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THESIS

**TACTICAL DMS:
A GLOBAL BROADCAST SERVICE OPTION**

by

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June 1996

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TACTICAL DMS: A GLOBAL BROADCAST SERVICE OPTION

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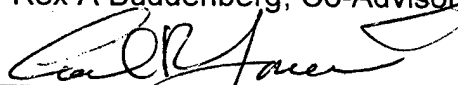
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ABSTRACT

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LIST OF ACRONYMS AND/OR ABBREVIATIONS

ACP	Allied Communications Policy
ATM	Asynchronous Transfer Mode
AUTODIN	Automated Digital Network
BER	Bit Error Rate
BMC	Broadcast Management Center
CINC	(Theater Unified) Commander In Chief
CMTP	Connectionless Message Transport Protocol
CONUS	Continental United States
COO	Concept Of Operations
DBS	Direct Broadcast Service
DCP	Distributed Communications Processor
DDN	Defense Data Network
DISA	Defense Information Systems Agency
DISN	Defense Information Systems Network
DMS	Defense Message System
DoD	Department of Defense
DoN	Department of the Navy
EBCDIC	Extended Binary Coded Decimal Interchange Code
EDAC	Error Detection and Correction
EHF	Extremely High Frequency
email	electronic mail
EMCON	Emissions Control
FEC	Forward Error Correction
FLTBCST	Fleet Broadcast
GBS	Global Broadcast Service
GCCS	Global Command and Control System
GENSER	General Service (message)
GHz	Giga-Hertz
GOSIP	Government Open Systems Interconnect Profile
HF	High Frequency
IP	Internet Protocol
IPv6	Internet Protocol version 6
ISDN	Integrated Services Digital Network
ITU	International Telecommunications Union
JANAP	Joint Army, Navy, Air Force Publication
JCS	Joint Chiefs of Staff
JWID	Joint Warrior Interoperability Demonstration
LAN	Local Area Network
LANT	Atlantic (ocean)
MFI	Multi-Function Interpreter
MHS	Message Handling System
MHz	Mega-Hertz
MILSATCOM	Military Satellite Communication

MISSI	Multilevel Information Systems Security Initiative
MNS	Mission Need Statement
MPEG	Moving Pictures Expert Group
MTA	Message Transfer Agent
MTS	Message Transfer System
NAVCOMPARS	Navy Communications Processing and Routing System
NAVCOMSTA	Naval Communications Station
NAVMACS	Naval Automated Communications System
NCP	Navy Communications Processing and Routing System
NCTAMS	Naval Computer and Telecommunications Area Master Station
NIPRNET	Non-classified Internet Protocol Routed Network
NRO	National Reconnaissance Office
NSA	National Security Agency
ORD	Operational Requirements Document
OSI	Open Systems Interconnection
PAC	Pacific (ocean)
QPSK	Quadrature-Phase Shift Keying
SCI	Special Compartment Information
SHF	Super High Frequency
SIPRNET	Secret Internet Protocol Routed Network
SMTP	Simple Mail Transport Protocol
SPAWAR	Space and Naval Warfare Systems Command
TAC-3	Tactical Advanced Computer (version) 3
TACINTEL	Tactical Intelligence
TCP	Transmission Control Protocol
TDM	Time Division Multiplex
TS	Top Secret
UA	User Agent
UDP	User Datagram Protocol
UFO	UHF Follow-On (satellite)
UHF	Ultra High Frequency
USMTF	United States Message Text Format
USSB	United States Satellite Broadcasting (Corporation)
VLF	Very Low Frequency
WAN	Wide Area Network

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EXECUTIVE SUMMARY

DoD messaging is moving to the Defense Message System (DMS). DMS is a hardware, software and information management solution designed to meet all DoD messaging requirements and allow for interoperable electronic messaging. In a most basic sense, DMS can be viewed as the set of components via which a DoD-wide electronic mail (email) service will be established. Military messaging requirements, met in the past by service-specific (and often incompatible) systems, will now be incorporated into a DoD-wide multimedia email environment. Beyond the changes in messaging standards, DMS alters the way DoD conducts its messaging and over what links these new messages are passed. DoD DMS transition efforts are aimed at complete replacement of the current Automated Digital Network (AUTODIN) message-switched network by the year 2000.

However, while shore-based users can rely on such infrastructure technologies as Integrated Services Digital Network (ISDN), Asynchronous Transfer Mode (ATM), commercially-standardized network protocols and high-throughput physical links to increase their DMS performance and connectivity, these same technologies have not effectively been applied at the mobile, tactical level. Furthermore, the Navy must contend with DMS connectivity to highly mobile subscribers, who also function as the basic element of the naval operational force, namely ships. Complicating the Navy's DMS implementation efforts is the fact that tactical units must often, due to bandwidth limitations and operational security (i.e. Emissions Control - EMCON), commit solely to a "receive only" communication link known as the Fleet Broadcast. It is expected that a

broadcast capability must be maintained by the Navy's emerging DMS infrastructure. However, the Navy's Fleet Broadcast subsystem is ill-equipped to handle DMS message traffic. Increased throughput requirements, incompatible protocols, security concerns and system management issues must be addressed prior to effective DMS connectivity in a broadcast mode. Many technical and managerial aspects of the Fleet Broadcast must be modernized if it is to become a seamless extension of the DMS infrastructure into the tactical environment. Current proposal for resolving the limitations of applying DMS over broadcast links call for the translation of the DMS message back to an AUTODIN format prior to transmission over all MILSATCOM communication systems, both duplex and broadcast. This is admittedly a short-term solution.

High data-rate direct broadcast services, recently perfected by civilian industry, represent a unique and timely opportunity for the US military to vastly improve its data dissemination architecture. In an attempt to effectively apply this emerging technology, the US military is developing a new satellite-based data dissemination system, based on similar commercial systems, known as the Global Broadcast Service (GBS). The application of GBS as a "next generation" Fleet Broadcast offers an expansive leap in tactical broadcast communication capability. Furthermore, this broadcast technology can be effectively adapted to the DMS architecture. In this manner, not only is the Navy's message broadcast capability expanded, but the overall load on duplex MILSATCOM systems is reduced.

DMS broadcast to the tactical environment via GBS and the integration of this capability into the DISN requires the application of relatively new network addressing

and mobile user routing protocols. Adaptation of the current DMS messaging protocols is also required. The proposed communications architecture provides for a high data-rate message broadcast system, capable of carrying DMS traffic to mobile units. The proposed system offers a near-term tactical DMS utility while more robust duplex links are developed. It also identifies the frame-work for a long-term DMS "Fleet Broadcast" link.

Ultimately, DMS will be implemented in all DoD environments: tactical, strategic, fixed and mobile. However, while DMS efforts are aimed at providing multimedia messaging capabilities, the networks used to pass these messages are not being expanded to meet the new requirements. This thesis attempts to present one possible method of integrating the DMS and GBS systems. This effort is undertaken in order to explore how the DMS messaging capability can be extended to the mobile, tactical user via a new, more robust broadcast subsystem. While a duplex DMS connectivity to tactical units is certainly essential, this thesis focuses on an architecture and concept of operations for a high data-rate, DMS capable broadcast system.

I. INTRODUCTION AND PROBLEM OUTLINE

A. THE DMS CONCEPT

The Department of Defense (DoD) is currently transitioning from service-specific (and often incompatible) messaging systems to the Defense Message System (DMS). The DMS complies with the X.400/X.500 international standards for digitally switched message¹ (non-voice) traffic. DMS is a hardware, software and information management solution designed to meet all DoD messaging requirements and allow for interoperable electronic messaging. In a most basic sense, DMS can be viewed as the set of components via which a DoD-wide electronic mail (email) service will be established. Ultimately, DMS will be implemented in all DoD environments: tactical, strategic, fixed and mobile. Basic DMS requirements, as outlined by the Assistant Secretary of Defense for C3I, include: [Ref. 1]

- support for exchange of electronic messaging at all classification levels
- maintain a high level of reliability and availability
- interoperate with current messaging systems until fully implemented
- field a single system that supports both formal (organizational) and informal (individual) message communications.

DMS long-term goals include the phasing out of existing messaging systems, the automated extension of email services to the end user, and increased messaging connectivity throughout DoD with expanded capabilities such as text,

¹ Throughout this thesis "message traffic" refers to non-voice organizational communications of an official nature or of general operational interest.

video, images and pre-recorded voice. The DoD's ultimate DMS goal, as stated on the DMS World Wide Web home page, is a secure, accountable, reliable writer-to-reader messaging system for the warfighter at a reduced cost.

1. Basic X.400/X.500 Concepts

An in-depth review of all DMS functions, components and structure is not undertaken in this thesis². However, some specific aspects and technologies which form the basis of DMS and the X.400/X.500 email protocols are reviewed in the following subsections.

DMS is based on the 1988 X.400 email protocol and the Open Systems Interconnection (OSI) network model, which divides the various processes involved in electronic data transfer into seven distinct layers (refer to Appendix A). These layers are each responsible for specific aspects of data manipulation and network interaction.

a. X.400

The X.400 email protocol is composed of three environments (refer to Appendix B). The inner-most environment is the mail transfer system (MTS) which provides the basic service of moving messages from one place to another. It consists of Message Transfer Agents (MTAs) that communicate with each other via an application protocol known as P1. The lower-level network and transport protocols used between MTAs are not specified by X.400. P1 assumes

² A comprehensive DMS technical overview can be found in Ref. [3].

the presence of these lower-level protocols, but makes little demand on them; this allows X.400 packets to be carried over physical links by various routing and transport protocols. This lack of reliance on lower protocols is beneficial when applied to the vast majority of networks, which are based on duplex connectivity; but causes problems when applied to a simplex (one-way) communication link.

The second environment, called the message handling system (MHS), incorporates user agents (UA) which act as the user's direct email interface mechanism. A UA allows the user to create, edit, send, receive and view X.400 email messages. Personal computers are the most common UA implementation. Several UAs can be connected to a single MTA. The protocols used to connect UAs to MTAs are known as P3/P7. The final, outer-most, layer incorporates the users and the type of network system environment (e.g., single unit, squadron, organization) over which the MHS is implemented.

Although DMS will maintain the DoD's five levels of priority for message delivery, these levels will be mapped to the three precedence levels inherent in X.400 for actual transport. Table 1 compares the speed of delivery service for X.400 and the current DoD message precedence and delivery criteria.

Current DoD Precedence	DoD Delivery Standards	X.400 Precedence	X.400 Delivery Standards	Assumed Message Size (bytes)
CRITIC	3 min	URGENT		5,400
FLASH	10 min	URGENT	< 3 min	7,000
IMMEDIATE	20 min	NORMAL		1 million
PRIORITY	45 min	NORMAL	< 20 min	2 million
ROUTINE	8 hours	NON-URGENT	< 8 hours	2 million

Table 1. DMS Speed of Service Comparisons. After Ref [2].

b. X.500

X.400 addresses are composed of long attribute and value strings (e.g., country: *USA*; enterprise: *US Navy*, organization: *CINCLANTFLT*, suborganization: *Second Fleet*, unit: *USS SHIP*, title: *CO*)³. Because these strings are difficult to remember, a user-accessible central store of X.400 addresses was required. This address database is implemented with international standards known as the X.500 series data store protocols. These protocols allow users to query a distributed directory for any data they require (e.g., X.400 email addresses and/or demographic data).

³ As an example, the Simple Mail Transfer Protocol (SMTP) used extensively on the commercial Internet uses a simple string of domain, subnetwork, network and user identifiers, where the user's identifying script is separated from the network addresses by an "@". An SMTP address looks like: user@subnet.network.domain

2. DMS Role Within the DISN

Beyond the changes in messaging standards, DMS alters the way DoD conducts its messaging and over what links these new messages are passed. Figure 1 depicts the transitional relationships between the current Defense Data Network (DDN) communication subsystems and the proposed integrated communication architecture commonly referred to as the Defense Information Systems Network (DISN). DMS will act as the message traffic component of the DISN. DoD DMS transition efforts are aimed at complete replacement of the current Automated Digital Network (AUTODIN) message-switched network by the year 2000 [Ref. 2]. All DISN (and therefore DMS) transition efforts are coordinated by the Defense Information Systems Agency (DISA). Each service maintains a DMS Program Office chartered to implement DMS transition components.

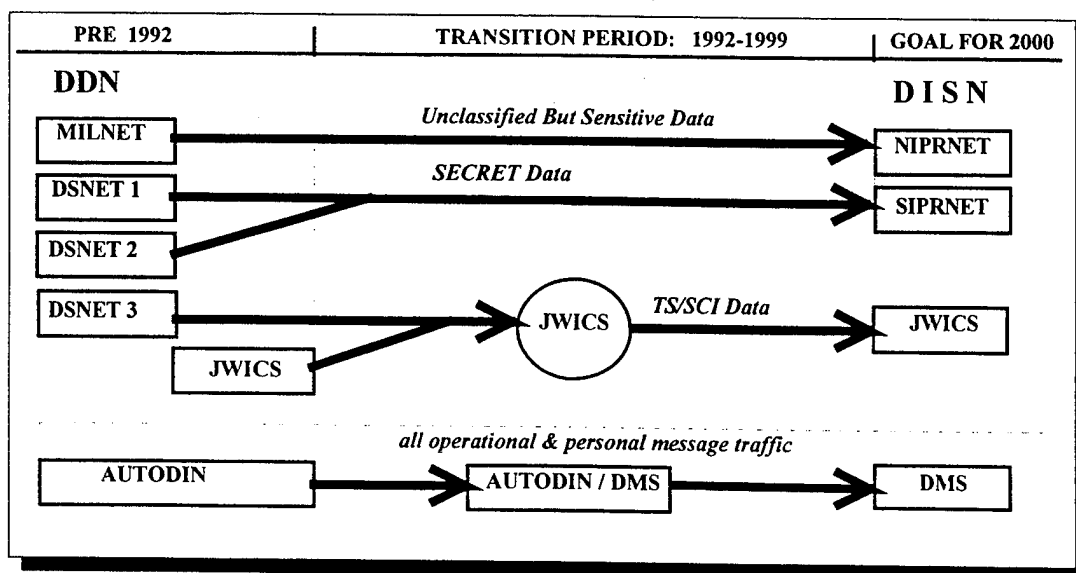


Figure 1. DDN to DISN Transitional Relationships. After Ref [3].

3. DMS and the US Navy

There are approximately 11,235 communication sites⁴ in the US Navy, distributed over 273 land-based commands and 369 ships. Additionally, the Navy provides communication support to approximately 390 non-DoN organizations [Ref. 4]. There is no official documentation of the amount of intra- and inter-DoN email communications over the commercial Internet. However, a 1994 study indicated that at least 18 different types of proprietary email systems are in operation throughout DoN activities and commands [Ref. 4]. The Navy's DMS solution proposes to standardize these systems and provide email connectivity to both shore and sea-based operators with the same elements of service denoted for all DMS users. However, while shore-based users can rely on such infrastructure technologies as ISDN (Integrated Services Digital Network), ATM (Asynchronous Transfer Mode), commercially standardized protocols and high-throughput physical links to increase their DMS performance and connectivity, these same technologies have not effectively been applied at the mobile, tactical level.

Furthermore, the Navy must contend with DMS connectivity to highly mobile subscribers, who also function as the basic element of the naval operational force, namely ships. Bandwidth limitation, both at the receive station

⁴ Communication "site" is defined here as a dedicated communication center, transmit/receive facility or station. Theoretically, DMS expands this definition to include the individual email user.

(ship) and relay satellite, is by far the most constraining factor in the full implementation of DMS connectivity to all US Navy subscribers [Ref. 4].

The Navy must also, in its tactical DMS implementation efforts, meet several required operational messaging characteristics, defined by DISA, which denote the base performance standards expected of all DMS implementation efforts within DoD [Ref. 5]. They include:

- Maintain a probability of message loss less than 1 out of 100 million
- Provide for changing traffic loads, accommodate peak traffic volumes in times of crises (150% of peacetime rates) and war (200% of peacetime rates)
- Ensure writer-to-reader system availability of at least 98.5%
- Maintain 25% system growth allowance
- Store at least 10 days of organizational messages
- Maintain storage capacity for 30 days of audit information
- Guarantee organizational message delivery of at least 99.99%.

Complicating the Navy's DMS implementation efforts is the fact that tactical units must often, due to bandwidth limitations and operational security (i.e., Emissions Control - EMCON), commit solely to a "receive only" communication network known as the Fleet Broadcast (FLTBCST). It is expected that a broadcast capability must be maintained by the Navy's emerging DMS infrastructure. The technical and information management details of the Navy's current Fleet Broadcast system are reviewed in Chapter II of this thesis.

B. DMS IN THE CURRENT NAVY BROADCAST ENVIRONMENT

New messaging architectures and higher bandwidth transmission subsystems are the key to the world-wide communication infrastructure outlined in the Navy's COPENICUS concept. DMS is viewed by its proponents as a critical springboard for future application of information management technologies within the DoN and DoD. Moreover, any new information system demands a review of how to best organize, manage and disseminate that information. This is especially true of DMS, where not only is equipment to be replaced, but where the entire concept of how the DoD accomplishes its message communications will be altered.

Current Navy fleet broadcast architectures cannot meet the new DMS requirements. Increased throughput requirements, incompatible protocols, security concerns and system management issues must be addressed prior to effective DMS connectivity in a broadcast mode. These points are detailed below.

1. Bandwidth Limitations

The primary causes of communication backlogs within the current FLTBCST are the slow transmission rates of the satellite subsystems (maximum: 9600 bps). Average Navy message size was determined in 1990 to be 2,544 bytes [Ref. 7]. DMS will, without doubt, increase average message size due to:

- the higher overhead associated with the X.400 protocols
- an expanded messaging capability (e.g., multimedia attachments)

- overhead added by application of security protocols
- other reasons presented in detail later in this thesis.

The ease of use and widespread application of DMS can also be expected to increase the number of messages sent between users, in much the same manner as the recent explosion of email use over the commercial Internet. The current throughput capabilities (measured in bps) of the DoD's Military Satellite Communication (MILSATCOM) systems are far less than what is required for effective DMS connectivity to tactical units.

The bandwidth expansion capacity of current shipboard systems are stifled, mostly due to limitations in receive antenna size. Use of commercial C and Ku-band satellites, with associated large (2-3 meter) receive antennas may alleviate bandwidth constraints on large platforms such as aircraft carriers and amphibious ships, but it does not address the needs of smaller escorts and submarines with their limited antenna support structures. Some evolving antenna technologies, such as phased array antennas, may well alleviate the limited antenna space concerns on smaller ships, but widespread application of these technologies will not occur in the near term.

Smaller, higher bandwidth, satellite transmission systems must be examined and applied to the Navy's DMS tactical environment as message size and traffic load increase. When variation in antenna size and receiver sensitivity is limited, increased data throughput can be obtained only by using higher frequency bands, increasing satellite downlink transmission power or application

of higher data compression ratios. A recently developed broadcast satellite system, which meets these demands, is the focus of Chapter III of this thesis.

2. Protocol Incompatibilities

As previously presented, DMS is based on the 1988 X.400 email protocol and the Open Systems Interconnection (OSI) model (refer to Appendix A). Layers 1 through 3 involve the physical transport, addressing and routing of the datagrams, while layers 4 through 7 (of which X.400 is a part) are responsible for higher levels of datagram sequencing, error detection/correction, formatting and presentation to the user. DMS messages, although formatted with the X.400 protocol, are predominately carried over the Transmission Control Protocol / Internet Protocol (TCP/IP) based NIPRNET. TCP/IP is a set of transport, addressing and routing protocols (equivalent to OSI layers 3-4) developed by DoD for use on the Internet. They remain the most common set of network interconnection protocols on the Internet.

The general benefit of the OSI model is a strict division of networking responsibilities. Each layer is wholly responsible for very specific aspects of data manipulation and network interaction. Each layer interacts only with the layer immediately below and above it. However, when a network connection is made between two nodes, each layer located at one end-node also communicates (exchanges specific data) with its counter-part on the other end node (true for all layers above the network layer). This ability to establish a duplex link and exchange data back and forth between nodes is known as connection-oriented

connectivity. The connection-oriented requirements inherent in the application of X.400 over TCP/IP networks increases the number of transmitted data bits required to affect a message transfer.

a. TCP/IP

The Internet Protocol (IP) is designed for use in interconnected computer communication networks. IP provides for transmitting blocks of data, called datagrams, from sources to destinations, where sources and destinations are identified by fixed-length numerical addresses. IP also provides for fragmentation and reassembly of long datagrams. Each datagram is treated as an independent entity unrelated to any other datagram. IP does not provide reliable communications. There are no acknowledgments and there is no error correction for datagrams, only a header checksum. There is no facility for the retransmission of lost datagrams or for controlling the flow of datagrams.

All reliability, error control, retransmission and sequencing actions are carried out by the next higher layer in this model, known as the Transmission Control Protocol (TCP). TCP insures that the higher application layers receive datagrams that are error-free and in correct sequence. However, TCP can only operate effectively in a connection-oriented network environment. This means that TCP expects the destination node to send acknowledgments whenever it successfully receives a datagram. All datagrams (e.g., X.400 message packets) must therefore travel along a circuit path in which both the sending node and the intended receiving node can communicate with each other. Basically, a two-way

data exchange session must be established and maintained between the sending node and the receiving node in order for datagrams to be passed.

b. X.400/TCP and Simplex Links

During an X.400 message transfer session, both the P1 protocol and the TCP layer of the originating node communicate directly with their respective counterparts on the recipient node. Basically, the originating MTA's P1 expects to receive acknowledgment from the recipient MTA prior to and during message transfer. These acknowledgment datagrams are in addition to the retransmission requests commonly sent back and forth between the TCP layers. This duplication of effort does not pose immediate concern if the two network nodes maintain a duplex connectivity. In that case, the two protocols (P1 and TCP) can each request and receive individual acknowledgments. However, this duplication of effort does add to link congestion since an undeterminable number of acknowledgment packets are required to affect a datagram transfer. Furthermore, this duplication of effort also presents problems when applied to simplex links where the protocols cannot exchange data. Solutions which satisfy the acknowledgment needs of *both* the P1 and the transport layer (TCP) must be incorporated to effect a successful message transaction over a broadcast link.

The need to satisfy the acknowledgment requirements of both the P1 and TCP protocols represents the primary hindrance to the application of DMS in "connectionless" network architectures, of which (simplex) broadcast

communications are a part. In order to satisfy the needs of the transport layer over a simplex link, (e.g., over Fleet Broadcast) datagrams must contain both packet sequence data and imbedded error detection and correction (EDAC) schemes, known as forward error correction (FEC); both require additional data bits. These additional bits are critical since the receiving node (e.g., a ship's MTA) cannot immediately send back requests for packet retransmission if it finds an error or fails to receive a packet. However, with DMS, the acknowledgment demands of the originating MTA's P1 must also be met, since it expects to interact (exchange data) directly with the P1 layer of the receiving MTA.⁵

c. *Mobile User Connectivity*

The DISN lacks a capability which is paramount to successful, seamless integration of US Navy tactical units into its network. Specifically, TCP/IP, as presently incorporated by the NIPRNET, cannot effectively route datagrams to units unless they maintain a network (DISN) interface via the same network host. The IP protocol ties the physical location of a node with its network connection. If a node leaves its network and then regains connectivity via another host interface (e.g., a user leaves their home office and wishes to receive all their email via a network in another city), it must be assigned a new IP address by the new network interface host. This new IP address must be updated by all network routers and nodes in order for the mobile node to

⁵ This need for application-layer connectivity is not unique to DMS. Most applications designed for use on networks rely on duplex links over which to coordinate information transfer.

continue receiving datagrams. In Navy terms, a ship transitioning from the Atlantic to the Mediterranean must be assigned a completely new IP address. This new address must then be broadcast to all DISN users and routers before seamless re-routing of traffic to the ship can occur. Message originators which use the ship's old IP address will be unable to effect a successful connectivity with it. If IP addresses change often and new address updates are not quick enough, then network connectivity at the routing (IP) layer can easily be lost. The scalability and seamless integration of such a mobile-user capability into a network as large as the DISN is not a trivial concern.

3. Security Concerns

The DISN, unlike AUTODIN, is not based on a secure network infrastructure. The new DISN packet-switched architecture is divided between two sublinks: the NIPRNET and the SIPRNET (Secure Internet Protocol Routed Network, see Figure 1). DMS messages will be transported over the NIPRNET. Instead of encrypted links, which now dominate the AUTODIN messaging architecture, DMS will rely on a variety of security formats whose purpose is the security and encryption of the message itself, vice the physical link over which it travels. The National Security Agency's (NSA) MISSI (Multilevel Information Systems Security Initiative) program is responsible for DMS message security products and implementation. A primary concern is the loss of security during message processing and routing. MISSI-encrypted DMS messages (multimedia attachments are also encrypted) must be delivered in unaltered form to the

reader. MISSI security also allows for authentication of message sender via a digital signature which is electronically "stamped" on the message. In the context of this thesis, these important security features are viewed as even more bits which must be added to the DMS message prior to transmission.

4. Proposed solutions

There are currently two proposals for resolving the limitations of applying DMS over broadcast links. The first method (and the one currently being examined for Navy tactical DMS implementation) calls for translating the X.400/DMS message back to an AUTODIN format prior to transmission over all MILSATCOM communication systems, both duplex and broadcast. The key limitation of this proposal is the MILSATCOM bandwidth constraints already discussed. Furthermore, this proposal violates the basic DMS elements of service for the tactical users. It does, however, offer a near-term solution to the protocol, security and mobility issues. The second (longer-term) proposal calls for a direct DMS broadcast capability which involves an alteration of the P1 protocol. This new protocol, the Connectionless Message Transport Protocol or CMTP, will allow the X.400 application to operate over a simplex link. However, it does not address the lower-layer routing and transport concerns. A more detailed review of these proposals and their limitations is undertaken in Chapter IV of this thesis.

C. THESIS SCOPE

Military messaging requirements, met in the past by service-specific systems, will now be incorporated into a new DoD-wide email environment. DISA has been appointed the DMS management agent and as such is responsible for the integration and interoperability of all DMS subsystems. A decentralized approach to subsystem integration and compatibility has been chosen. Each service has been tasked only to find solutions to its particular messaging needs, with all proposed DMS architectures containing a standardized interface link to the DISN. The interior details of the DISN are yet to be finalized and are seen as beyond the scope of the service system developer's requirements. Key to the effective integration of this distributed, systems engineering process is the proper implementation of accepted interface protocols and formats by all concerned.

Tactical DMS implementations must deal with more complex connectivity hurdles than shore-based systems, as outlined in the previous sections. The interface connection from the tactical user to the common DISN cannot be reduced to an electronic line pointing to a "cloud". Realistic answers must be outlined and management issues resolved.

While a duplex DMS connectivity to tactical units is certainly essential, this thesis focuses on a specific technical solution to the broadcast DMS problem. An architecture and concept of operations for a high data-rate, DMS capable

"next generation" Fleet Broadcast System is the central goal of this thesis.

Options for management and implementation of that system are also outlined.

II. USN FLEET BROADCAST

The US Navy's broadcast messaging system is known as the Fleet Broadcast (FLTBCST). The current FLTBCST subsystem is an automated, simplex (shore-to-ship) service which uses low-rate MILSATCOM transponders to broadcast Top Secret and below General Service (GENSER) message traffic to ships and other mobile units. Messages destined for broadcast are automatically prioritized, formatted, stored, backlogged and routed at Naval Computer and Telecommunications Area Master Stations (NCTAMS) by the Navy Communications Processing and Routing System (NAVCOMPARS or NCP). NAVCOMPARS is based on early 1970's mainframe technology and integrates the AUTODIN with the operational fleet communication subsystems.

A. NCTAMS PROCESSING

The Navy operates four NCTAMS: Norfolk, Virginia (LANT); Bagnoli, Italy (MED); Wahiawa, Hawaii (EASTPAC), and Finegayan, Guam (WESTPAC). These stations provide satellite and HF connectivity to fleet users. Theater Unified Commanders (CINCs) maintain operational control of their NCTAMS and the content of the Fleet Broadcast. NCTAMS currently maintain an interface to the DISN as well as the message-switched AUTODIN and circuit-switched voice subsystems. The HF broadcast capability serves as a back-up method of message dissemination.

1. Message Processing

Messages received by the NCP are first recorded in their original format on hard disk memory. The message is then converted to a common format, 8 bit Extended Binary Coded Decimal Interchange Code (EBCDIC), for processing. The NCP system analyzes the message for priority, suspected duplication, routing indicator and distribution assignment. Transmission scheduling and queuing are also automated, with each message processed in a first-in, first-out manner, based on precedence level. Human interface and control is provided via a command line terminal, where system monitoring, testing and manual message injection is performed. The processed message is again recorded on hard disk prior to transmission. A 1985 Space and Naval Warfare Systems Command report found that an average of 12,000 broadcast messages are processed by each NCTAMS daily, while average daily broadcast traffic received by a major combatant ship is less than 5000 messages [Ref. 6].

2. Message Transmission

The Fleet Broadcast is transmitted to tactical users via three frequency bands: SHF/UHF (satellite links), HF and VLF. The satellite system, controlled at NCTAMS sites, uses an SHF direct sequence-spread spectrum uplink. The signal is downconverted by the satellite to the UHF band and then downlinked to small omni-directional antennas onboard ships. The broadcast is composed of 16 75bps subchannels which are time-division multiplexed (TDM) into a

composite 1200bps data stream: eleven general service (GENSER) traffic channels, two weather channels, two Special Compartmented Information (SCI) level Tactical Intelligence (TACINTEL) channels and one system synchronization channel. Once received onboard ships, the UHF downlink is demodulated and demultiplexed; GENSER and weather subchannels are routed to the ship's message processor, known as the NAVMACS (Naval Automated Communications System), while the intelligence traffic is forwarded to the ship's TACINTEL processors and teletypes.

FLTBCST messages conform to a variety of formats including: US Message Text Format (USMTF), Joint Army, Navy, Air Force Publication standard (JANAP) 128 , and the Allied Communications Policy (ACP) standard 121/127. Figure 2 depicts a simple overview of a ship's current FLTBCST communication subsystem, its major components and their integration.

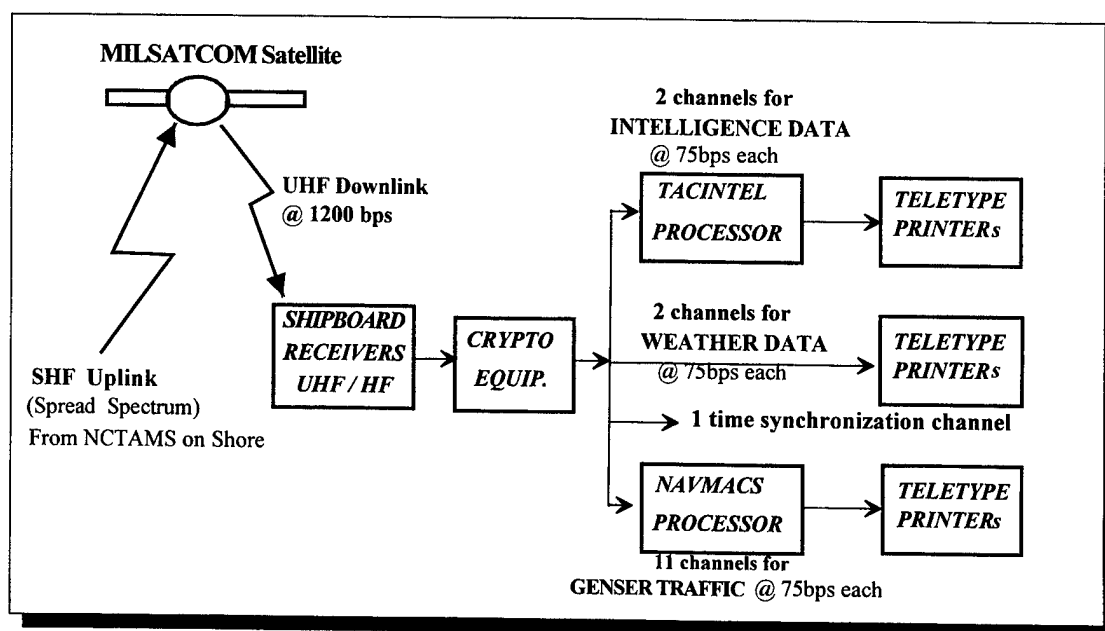


Figure 2. Shipboard Fleet Broadcast Subsystem. After Ref [6].

B. NAVCOMPARS II

The Navy's next generation shore-based message processing system, NAVCOMPARS II (NCP II), incorporates a secure software operating environment and a distributed database architecture operating on a Tactical Advanced Computer-3 (TAC-3) computer. Under the NCP II architecture, NCTAMS internal subsystems are connected by an Ethernet (10Mbps) network and maintain both a Government Open Systems Interconnect Profile (GOSIP) and a more-widely used TCP/IP external connectivity. NCP II's TAC-3 computer processes messages in 8-bit ASCII format. Input messages are converted from their particular formats (primarily JANAP 128 and ACP 127) to 8-bit ASCII, processed with much the same functionality as the original NCP, then converted to a 5-level baudot format prior to transmission. Conversion of outbound messages from ASCII to baudot is accomplished by a gateway known as the Distributed Communications Processor (DCP).

All four NCTAMS will be linked via the DISN (specifically the NIPRNET). This NCTAMS Wide Area Network (WAN) will provide for world-wide Navy communications integration and synchronization, the sharing of databases, user location data, and fast secure routing of message traffic. Messages passed on this WAN are individually encrypted for security (except for header data). Initial installation of NCP II at the four NCTAMS sites is expected by 1996. NCP II should be viewed as a much needed software and hardware upgrade to the current Navy communication architecture, not as a change in that architecture.

C. FLEET BROADCAST SYSTEM LIMITATIONS

A serious drawback to the continued use of the current Navy broadcast messaging network is that the NCP can process messages faster than the FLTBCST satellite (and HF) subsystems can transmit them. To account for the difference in input and output rate, NCP uses two output queues commonly referred to as Q1 and Q2. Q1, with a total capacity of 6,200 messages, serves as an accountability queue for messages while awaiting delivery to the transmission subsystem. Q2, with a total capacity of 10,000 messages, is a buffer memory store for messages queued for transmission but not yet confirmed as transmitted. The primary cause of communication backlogs (excessive Q1 queue size) within the NCP are the slow transmission rates of the satellite subsystems, not the processing capability of the NCP itself.

NCP II will greatly increase the processing speed and ease the operation and maintenance of Navy Fleet Broadcast management, but it will not address the bottlenecks caused by current transmission interfaces. Since, as presented in Chapter I, average message size can be expected to increase under the DMS, a central limitation of current Navy broadcast communication networks (under an AUTODIN or DMS paradigm) remains the restricted throughput available over military satellite systems.¹

¹ It is worth noting that this is the inverse of the modern commercial telephone problem. Commercial phone companies needed to develop faster switching systems (e.g., ATM switches) in order to keep up with the increased throughput offered by coaxial cable and fiber optics [Ref. 8]

Within the DMS framework, these physical limitations are compounded by the fact that X.400 connectivity was not viewed as a critical initial requirement of the NCP II; therefore NCP II will be fielded with no direct capability to accept and process DMS traffic. Effective application of gateways and interfaces to the current NCP and future NCP II, in order to adapt a DMS capability, poses a new set of interoperability, cost and management issues for near-term tactical DMS implementation.

III. GLOBAL BROADCAST SERVICE (GBS)

A. INTRODUCTION

Satellite reception equipment has been publicly available since 1976 when the first home satellite TV system was put into service in California [Ref. 9]. These early systems used 8-12 foot antennas to capture (often illegally) analog C-band TV broadcasts from national and local TV companies. At \$2000-\$4000 these TV "earth terminals" were not cheap. Furthermore, by 1990 most C-band TV signals were encrypted, forcing satellite TV owners to pay for decryption equipment.

In 1982, the FCC (Federal Communications Commission) and the ITU (International Telecommunications Union) allocated the 12.2-12.7 GHz band for direct-to-home satellite broadcast use. Then in 1984, United Satellite Communication Inc. (USCI) implemented the first commercial direct broadcast service (DBS) to US consumers. This venture offered satellite TV reception from a dedicated provider whose signal was broadcast by a leased Canadian satellite transponder. However, USCI failed to attract more than 7000 customers and went bankrupt in 1985 [Ref. 9].

In the time since those early attempts, advances in several commercial technologies have made high data-rate, digital data broadcast into small, inexpensive receive antennas a reality. Furthermore, this new technology is directly applicable to the US military's modern communication needs. This chapter will review the development of this new data broadcast technology, its military application and current military initiatives within this field.

B. HISTORY AND CONCEPT DEVELOPMENT

1. Direct Broadcast Service (DBS)

In 1994, *DirecTV* (a Hughes subsidiary) and *United States Satellite Broadcasting* (USSB) joined forces to provide a direct broadcast service (DBS) to the continental US. This satellite-based multimedia service combines high bandwidth links and large area coverage. There are three key components to the initial success of this new commercial technology:

- large selection of high-quality full digital audio and video channels (up to 200)
- small receive antenna (18") coupled to a small receiver/decoder
- low cost of equipment (under \$700).

The *DirecTV*/USSB transmission subsystem incorporates three geosynchronous satellites and two ground uplink sites. Input digital video and audio signals are first passed through MPEG (Motion Pictures Expert Group - an International Standards Organization entity) compression algorithms. Reed-Solomon forward error correction and security encoding is applied to the digital datastream prior to QPSK (Quadrature Phase Shift Keying) uplink modulation at 17.3-17.8 GHz. The satellite then downconverts the signal to the FCC approved frequencies (12.2-12.7 GHz) prior to broadcast. Once captured by the small receive antenna, the signal is demodulated and decoded by the home receiver and the selected channel is routed to the user's TV. Compression algorithms, FEC and satellite transponder saturation provide system data throughput of 23Mbps with a bit error rate (BER) of 10^{-10} . Figure 3 depicts a block diagram of the *DirecTV*/USSB commercial DBS system.

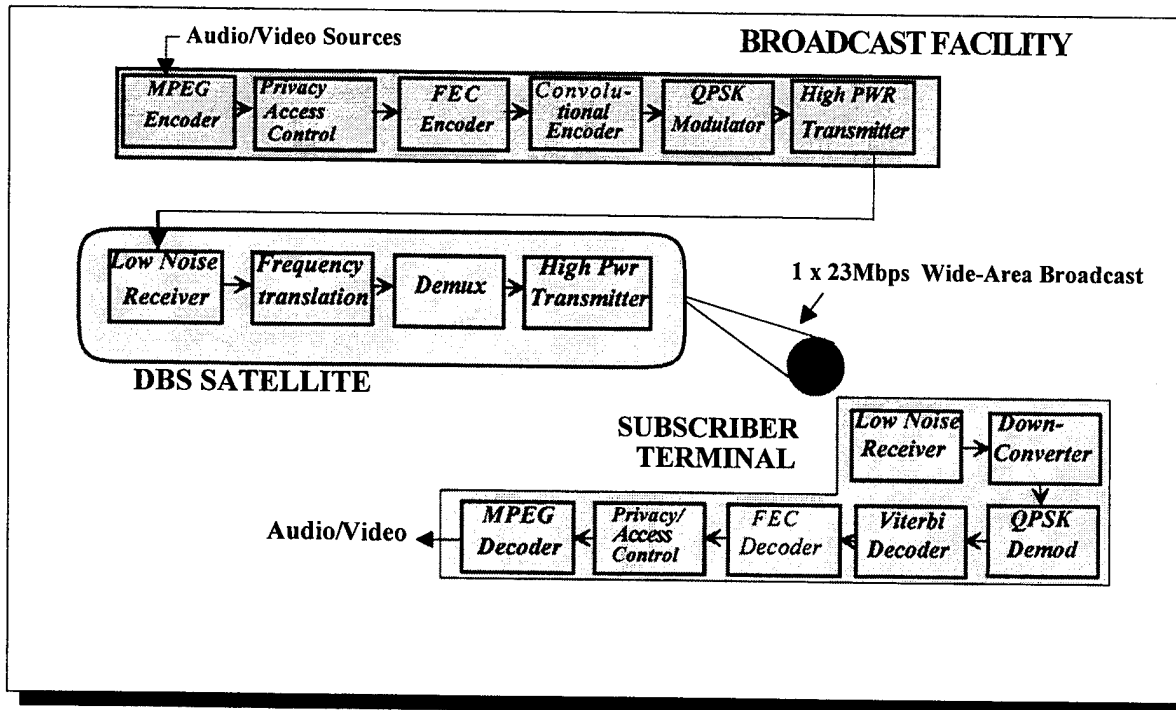


Figure 3. Commercial DBS System Block Diagram. After Ref [9].

2. Global Broadcast Service (GBS)

The military application of this new high data-rate, small receive antenna technology is known as GBS (Global Broadcast Service). In May of 1995, the US Joint Chiefs of Staff issued a Joint Mission Need Statement (MNS) which delineated the basic operational requirements of the GBS concept. In summary, the statement called for [Ref. 10]:

- a DBS-based system to provide secure simultaneous broadcast of multimedia information (video, data, imagery) to all approved recipients in a theater of operations
- world-wide coverage from 70° N to 70° S
- use of commercial off-the-shelf technologies and low risk, non-developmental equipment

- integration of the GBS system to the DISN
- security for data transmission at all classification levels from UNCLAS to SCI.

The GBS Joint MNS was followed by a draft GBS Concept Of Operations (ConOps), prepared by the US Space Command in August 1995. The GBS ConOps details preliminary implementation concepts and information management options, but does not address any system-specific parameters or architectures. The following points are presented in the GBS ConOps [Ref. 11]:

- primary interface for GBS service requests will be the GCCS (Global Command & Control System).
- GBS will augment current MILSATCOM systems, relieving them of much of the one way data traffic they now carry.
- GBS will incorporate a warfighter-responsive broadcast management structure which transmits data from CONUS uplink sites while also allowing in-theater (CINC-responsive) direct injection of data.
- two modes of operation are called for: wide area coverage and steerable "spot beams".
- GBS will provide three classes of tailored service: on-demand, continuous and periodic.
- the GBS system will maintain interoperability with IP-based addressing schemes already in use by DoD.

C. INITIAL GBS DESIGN

In November 1995, the Joint Staff validated the need for GBS, allocated approximately \$900M in funding and directed the Under Secretary of Defense (Acquisition and Technology) to establish a Joint Program Office to manage the program [Ref. 12]. The US Air Force was named lead agency/service for program

development, while the Army will formulate the GBS Operational Requirements Document (ORD).

There is no single, approved system architecture for GBS. However, initial GBS design concepts closely follow the commercial-based DBS. Figure 4 illustrates a typical GBS system structure and data flow. Major differences between GBS and commercial DBS include the use of ATM (asynchronous transfer mode), a switching technology used here in a transport/transmission role, and the use of bulk encryption for obvious security reasons¹. The GBS space segment and ground-based information flow/mangement concepts are detailed in the following subsections.

1. GBS Space Segment

There were, initially, two options for implementing the GBS space segment (satellites and transponders): leased commercial systems and military-only systems. While *LORAL Corporation (a Lockheed-Martin Company)* and *Hughes* have DBS-capable satellites in orbit, none of the current MILSATCOM communication systems is optimized for GBS service [Ref. 9]. In December 1995, the Joint Staff, based on recommendations by the Space and Naval Warfare Systems Command (SPAWAR), approved plans to place GBS transponders aboard the US Navy's Ultra

¹ The BER is significantly improved by means of double (concatenated) FEC encoding applied to the uplink signal in the form of Reed-Solomon (R-S) block encoding and convolutional encoding. Viterbi decoding is performed prior to decryption in order to reduce the error rate to a point where decryption can be done reliably. R-S decoding must be applied after decryption; otherwise the error-extension properties of the decryptor significantly degrade the improvement obtainable from R-S FEC. [Ref. 9].

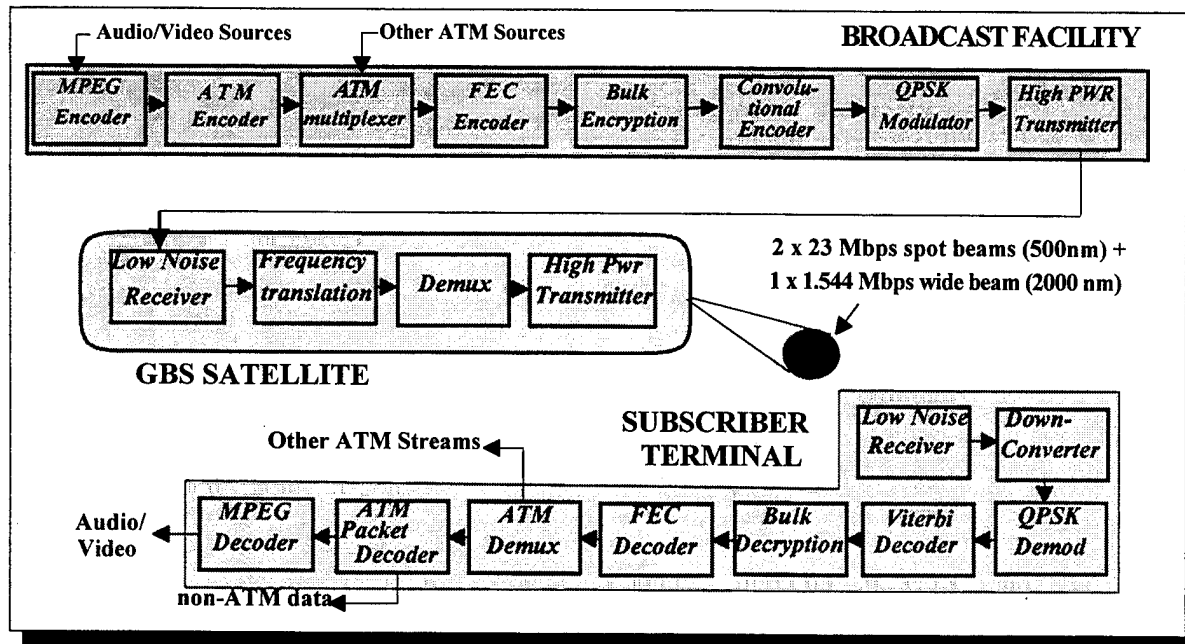


Figure 4. GBS System Block Diagram. After Ref [9].

High Frequency Follow-On (UFO) satellites. Proposals call for the SHF Fleet Broadcast transponders aboard UFO #8, #9 and #10 to be replaced with four GBS (EHF band) transponders, a modified power subsystem and improved heat dissipation structures prior to launch [Ref. 11]. There are currently five UFO satellites in orbit with four others scheduled for launch. These modifications will give each UFO satellite:

- two steerable GBS spot-beams (500 nautical mile diameter coverage each) operating at 24Mbps
- one wide area (2000 nm) low-rate GBS broadcast operating at 1.544 Mbps
- uplink accessibility from at least one (of four) NCTAMS site at all times.

Initial GBS/UFO operational capability is slated for the first quarter of 1998, with full system implementation within one year. The three modified UFO satellites will satisfy all space segment requirements set forth by the 1995 GBS Joint Mission Need

Statement. Table 2 summarizes the expected performance levels of the three GBS capable UFOs.

PARAMETERS	PER SPACECRAFT	GLOBAL
Number of Spot Beams	2	6
Transponders	4	12
Total Data Rate (Mbps)	96	288
Transponder Redundancy	5 for 4	
Downlink EIRP (dBW)	54.5	
Spot Beam Antenna Size (in.)	22	
Total TWT power (Watts)	120 (47% eff)	
Receive Antenna Size (in.)	18	
Uplink Frequency (EHF)	30-31 GHz	
Downlink Frequency (SHF)	20.2-21.2 GHz	

Table 2. GBS-Capable UFO Performance Summary. After Ref [13].

2. Broadcast Management Centers

While technical parameters and required modifications have been outlined for the GBS space segment, there is as yet no approved plan for the development of the information management infrastructure or coordination guidelines for the various data inputs and subsequent requests for service. However, there exists within the GBS development community a widely-accepted concept of a Broadcast Management Center (BMC) which must be capable of:

- integrating and processing ATM, non-ATM, video, imagery and weather data
- accepting and processing requests for GBS services from users over MILSATCOM and land-based networks
- maintaining data security up to the SCI level
- communicating with other BMCs in order to coordinate the GBS world-wide.

The GBS concept denotes both a CONUS-based BMC/uplink facility and theater CINC-controlled BMCs. However, the physical location of the broadcast sites, both CONUS and theater, has not been finalized. The JCS decision to modify Navy UFO satellites for a GBS role all but mandates the use of NCTAMS as GBS uplink sites. However, these NCTAMS, especially the new NAVCOMPARS II equipped sites, can also offer excellent GBS information fusion, management, coordination and data exchange capabilities as well.

NCTAMS, as previously noted, are CINC controlled communication centers which already gather, fuse, process and disseminate military data up to the SCI level. The information infrastructure and physical data links from the DISN to the warfighter via the NCTAMS communication hub are already in place. World-wide coordination of the GBS broadcast can be maintained via the DISN-based NCTAMS WAN. Furthermore, the open systems architecture of the NAVCOMPARS II TAC-3 computer system allows for easy integration of both ATM, non-ATM, video and audio datastreams. Requests for GBS services can be quickly processed, since NCTAMS currently operate the duplex systems marked for use as the warfighter's primary GBS service request channels. The NCTAMS currently operate within the same communication paradigm envisioned by the GBS concept, namely the direct dissemination of information and data to the warfighter. They represent the best method of integrating GBS services at the warfighter level without adding new information management layers to the theater CINCs. Figure 5 outlines how the internal data flow of a NCTAMS, acting as a GBS theater BMC, can be structured.

While NCTAMS may be well-suited as GBS theater BMCs, there remains a need as noted by both the GBS ConOps and MNS for a CONUS-based coordination and uplink facility. This site will have access to both the Atlantic and Pacific GBS satellites, while maintaining a centralized management capability for GBS services and requests world-wide. It would also serve as a primary JCS/National Command Authority data injection site. Current proposals indicate that this site may be managed by either DISA or USSPACECOM.

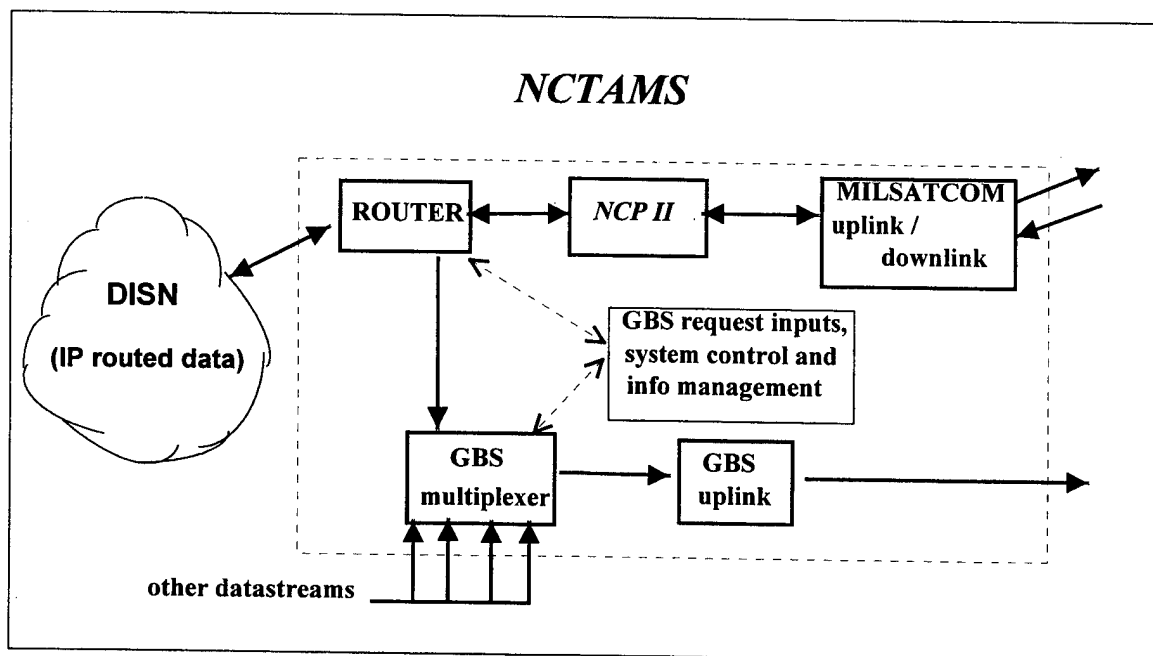


Figure 5. NCTAMS as a GBS Theater Broadcast Management Center.

D. CONCLUSIONS

High data-rate direct broadcast services, recently perfected by civilian industry, represent a unique and timely opportunity for the US military to vastly improve its data dissemination architecture without extended research and development of proprietary

systems. It is not a stretch to note that the US military's operational requirements for high throughput broadcast services have been outpaced by the commercially-led DBS technology explosion. Yet, preliminary integration of GBS signal processors and stabilized antennas onto mobile platforms (e.g., ships) has been accomplished. Fourteen US warships are currently outfitted with commercial DBS systems, and GBS systems have been installed on several tactical platforms, including aircraft [Ref. 14]. Theater-level GBS systems are operational in Europe (in support of NATO Forces in the former Yugoslavia), and in the continental US for testing and concept evaluation.

The GBS space segment architecture has, for the near future, been defined and set in motion. However, the current state of GBS information management, including data injection, requests for service and data format standardization, is seriously lagging behind its technical capabilities. CINC-controlled broadcasts, theater-direct data injection, and the effective integration of GBS with the DISN should compose the central focus of near-term GBS system development.

Use of the NCTAMS as a theater focal point for GBS broadcast coordination allows a relatively simple migration of the legacy Fleet Broadcast subsystem to a new, robust, high-speed data link. Weather, intelligence and GENSER message traffic, currently transmitted at 75bps can now be integrated onto a GBS (23Mbps) datastream for broadcast to the fleet and other tactical users. The details of this proposed integration and how it can extend a DMS broadcast to tactical mobile units is the focus of the next chapter.

IV. DMS BROADCAST OVER GBS

A. INTRODUCTION

Current Navy proposals omit any near-term DMS broadcast capability. Instead, Navy tactical DMS plans call for the conversion of X.400 messages to the legacy AUTODIN formats via a Multi-Function Interpreter (MFI). The MFI will "translate" messages back and forth between X.400 and AUTODIN formats. Converted messages are then transmitted over the MILSATCOM duplex/broadcast systems to tactical units. This is a short term solution. With AUTODIN replacement mandated by 2000 [Ref. 2], a more flexible, integrated tactical DMS solution needs to be articulated. Furthermore, a DMS broadcast capability needs to be developed to replace the existing Fleet Broadcast system.

As outlined in Chapter I, DoD development of a new protocol (CMTP) will allow data transmission from an originating MTA to a recipient MTA without the need for application-layer connectivity and acknowledgment of message delivery. This alteration, however, is directed at the higher (application) layer and does not address the general restrictions of TCP/IP over a connectionless link. The NIPRNET (on which DMS messages are carried) cannot be extended over a broadcast network, chiefly because TCP can only operate over a interactive (duplex) link.

In response to this limitation, it is expected that after development of CMTP, broadcast DMS will incorporate an unreliable, broadcast-capable

transport protocol known as UDP (User Datagram Protocol) [Ref. 15]. This simplex-capable protocol enables the transport of datagrams without sequencing information, error correction or the capability for retransmission of lost packets. It allows a sending node to transmit datagrams without responses (acknowledgments) from the receiving node. However, use of UDP is traded off against possible datagram non-delivery, error correction and/or duplication. UDP is an unreliable method for transporting operational message traffic.

The DMS Tactical Working Group reports that preliminary broadcast DMS testing can be expected after 1999 [Ref. 16]. Meanwhile, tactical units will receive messages of greater size (due to X.400/AUTODIN conversion overhead, MISSI and multimedia enclosures) over current MILSATCOM systems at 75-9600 bps.

This chapter presents a viable solution for DMS extension to the tactical environment and a conceptual outline for a robust broadcast network to replace the current Fleet Broadcast system. The concept integrates relatively new IP routing schemes with the GBS broadcast system presented in the previous chapter. The application of GBS as a "next generation" Fleet Broadcast offers an expansive leap in tactical broadcast communication capability. The proposed communications architecture is a high data-rate broadcast system, capable of carrying DMS traffic to tactical units. Some assumptions are made within the scope of the concept as presented; they are:

- NCTAMS are outfitted with GBS subsystems and routers capable of forwarding DMS data packets to them

- The DISN is fully operational and ties together all terrestrial DoD communication nodes
- The four NCTAMS are linked via the DISN, as outlined in Chapter I
- GBS is implemented with (as required) world-wide coverage.

B. ENABLING TECHNOLOGIES

The most critical aspect of this tactical DMS broadcast concept is the effective routing of messages to mobile units which are not continuously connected to the same network (DISN) interface. IP version 6 (IPv6) and mobile IP, both recently developed commercial protocol standards, address this requirement. Their use can effect a general, scaleable and easily implemented solution to the problem of broadcasting DMS messages to mobile, tactical units.

1. IPv6 and Anycast Addressing

IPv6, formalized by an Internet Engineering Steering Group in November 1994, was developed as an evolutionary improvement over the current Internet Protocol (IP version 4) [Ref. 17]. It can be installed as a software upgrade in Internet devices (routers, switches, gateways, bridges, etc.) and can coexist with systems using the current IPv4. Furthermore, IPv6 is designed to run well on high performance networks (e.g., ATM switched networks) while at the same time is still efficient for low bandwidth networks (e.g., MILSATCOM). Key upgrades from IPv4 to IPv6 include [Ref. 17]:

- **expanded routing and addressing capabilities.** IPv6 increases the IP address size from 32 bits to 128 bits, which supports more levels of addressing hierarchy, a much greater number of addressable nodes, and simpler auto-configuration of addresses.

- **header format simplification.** Some IPv4 header fields have been dropped or made optional, to reduce the processing cost of packet handling and to keep the bandwidth cost of the IPv6 header as low as possible despite the increased size of the addresses. Even though IPv6 addresses are four times longer than the IPv4 addresses, the IPv6 header is only twice the size of the IPv4 header.
- **improved support for options.** Changes in the way IP header options are encoded allows for more efficient forwarding, less stringent limits on the length of options, and greater flexibility for introducing new options in the future.
- **quality-of-service capabilities.** A new capability is added to enable the labeling of packets belonging to particular traffic "flows" for which the originator requests special handling, such as acknowledgments or "real-time" service.
- **authentication and privacy capabilities.** This includes the definition of extensions which provide support for authentication, data integrity, and confidentiality.
- **multiple addressing schemes.** Besides the standard unicast address, IPv6 incorporates multicast addressing and anycast addressing.

IPv6 represents a cost-effective, non-developmental, backward-compatible upgrade to the current IP protocol. It should be adopted for DISN implementation, even if just for its 128 bit address size and the ability to multicast data packets. Of primary importance to this thesis, however, is the development of a new addressing scheme within IPv6 known as the *anycast* address.

An anycast address is an IP address assigned to more than one network interface (e.g., router). Its primary property is that a datagram sent to an anycast IP address is routed to the "nearest" interface advertising that address.

"Nearness" is based on the routing protocol's measure of distance, vice physical distance, and takes traffic load and throughput speed into consideration

[Ref. 17]. In essence, anycast addresses are created when a node's unicast address (unique IP) is assigned to more than one network interface.

This new addressing scheme allows several network interfaces to receive and accept datagrams for a single node. In this manner a node can move from one network interface to another, share anycast addresses between itself, its new host and any other interface, and be assured that datagrams will be routed to it regardless of which interface actually receives them. Furthermore, a node can use its "home network" IP address as an anycast IP address, therefore negating the need to update or change its IP addresses every time it moves to a new network interface. A graphical representation of the anycast IP address concept is depicted in Figure 6.

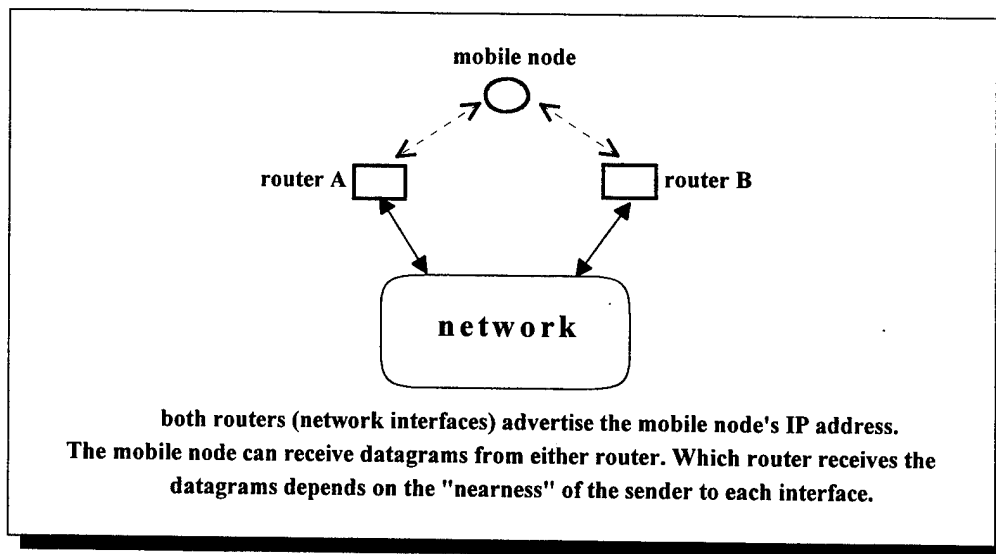


Figure 6. Anycast IP Address Scheme

In order to effect a seamless transfer of datagrams from all anycast interfaces to the intended recipient node, another routing scheme must be

incorporated. Specifically, the details of how datagrams are passed from an accepting anycast interface to a mobile recipient node, not physically connected to that interface, are outlined below.

2. Mobile IP

Documented in February of 1996 by the Mobile IP Working Group of the Internet Engineering Task Force, mobile IP allows automatic routing of datagrams to mobile nodes regardless of their geographic location or use of different network interfaces [Ref. 17]. The concepts behind mobile IP are not tied to the use of either IPv4 or IPv6; they can be implemented on a network which uses either (or both) protocols.

Current IP routing schemes assign a unique IP address to a network node. This IP distinguishes it from all other nodes on that network. If the node becomes mobile and cannot directly connect to its home network, it must change its IP address in order to receive datagrams while connected to the new network. This method can often cause loss of connectivity until the node's new IP address has been registered throughout the network's routing tables. Mobile IP offers a mechanism through which mobile nodes can connect to any network interface and still receive their data.

A mobile node is always associated with the IP address of its home interface, known as a *home agent*, even when physically away from its home. When away from home, the node is also associated with whatever interface it uses to reconnect to the network. The "away" interface, known as a *foreign*

agent, is registered with the home agent whenever the mobile node changes network interfaces. The home agent then reroutes all datagrams intended for the mobile node to that unit's foreign agent for delivery. The home agent "wraps" the datagrams in another IP datagram whose address header contains the IP address of the foreign agent. This process is known as "tunneling". The foreign agent "unwraps" the tunneled datagram, reads the IP address of the contained datagram and delivers it to the intended mobile node. In this manner the home agent maintains a virtual connection with the mobile node through the foreign agent which maintains a physical connection. Datagrams sent by the mobile node are delivered to their intended recipient using standard IP routing; they are not routed through a home agent. Figure 7 depicts a simple overview of the mobile IP concept.

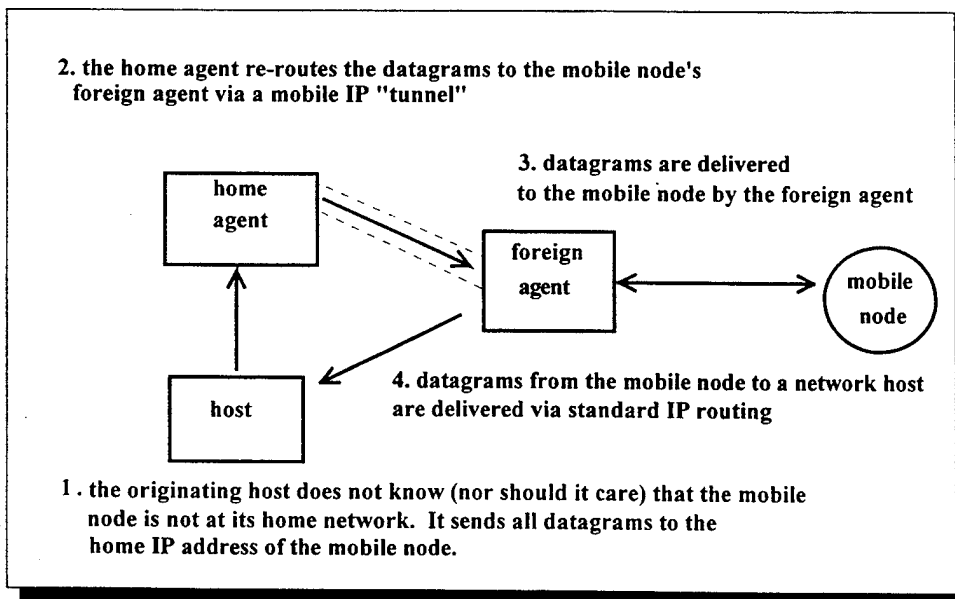


Figure 7. Mobile IP Routing Concept. After Ref [17].

C. GETTING A DMS MESSAGE TO A TACTICAL UNIT

In order to organize the DMS broadcast over GBS concept in a manner related to the operational aspects of tactical units, it is presented based on the following scenario: Two ships, homeported at Naval Station Mayport, Florida are preparing to get underway. USS SPRUANCE (DD-963) is scheduled for a six month Mediterranean deployment. USS GETTYSBURG (CG-64) is preparing for a two week exercise off the eastern US coast. SPRUANCE has Commander Destroyer Squadron 2 (COMDESRON 2) embarked. At the same time two other naval vessels, USS HOUSTON (SSN-713) and USNS ALTAIR (T-AKR 291), a civilian-manned rapid response cargo ship, are currently on station in the Pacific. The scenario will incorporate the flow of DMS messages as they are routed over the DISN (NIPRNET) and GBS to finally arrive at the correct unit. Details on the accomplishment of specific messaging processes are delineated as they occur.

1. Unit Pierside

In this case the tactical unit is no more than a building afloat on the water. DISN connectivity, and therefore DMS connectivity, are obtained via the port's Naval Communications Station (NAVCOMSTA) acting as home agent. Tactical units access the NAVCOMSTA's DISN routers via a dedicated, dial-up access phone line.¹ Eventual rewiring of homeports with coaxial cable, fiber optic or

¹ A very viable alternative is the continued reception of DMS traffic over the GBS system even while moored in port. This is, however, a doctrinal vice technical question and is not examined in this thesis.

even wireless (line-of-sight) extensions to pierside units would certainly be a welcomed improvement, but they do not alter the basic premise of tactical unit connectivity: tactical units are mobile and therefore must be able to disconnect from the pierside connections and not lose communication connectivity.

2. Unit Underway

Once underway, the direct DISN (and therefore DMS) interface for each tactical unit will be a NCTAMS. Twenty-four hours prior² to getting underway from homeport, communication personnel aboard the tactical units inform their respective homeport's NAVCOMSTA of their expected departure. This process is known as a communication guard shift or "com-shift". The IP routing tables within the NAVCOMSTA's DISN router and DMS MTA are updated to indicate that these subscribers are out of homeport. Each tactical unit's com-shift message really establishes an anycast address scheme between its NAVCOMSTA, the NCTAMS under whose control it falls, and itself. The NAVCOMSTA's routers are also updated to automatically reroute all message traffic intended for the underway unit back over the DISN to a NCTAMS using a mobile IP tunnel (home agent to foreign agent routing).

Concurrently, tactical units also report changes in their operational status to the NCTAMS nearest their homeport (or port of departure). The NCTAMS' DISN router is reconfigured by operators as a foreign agent, based on the

² Based on current USN policies. Efficient use of network technologies can considerably reduce the time lag involved in shifting communications guard.

tactical unit's requests, which accepts receipt of DMS messages addressed to the tactical unit. The NCTAMS MTA, which maintains a duplex DISN connectivity, accepts, error-corrects and reassembles all DMS datagrams. The in-sequence, error-free DMS message datagrams are then routed to the GBS subsystem (ATM multiplexer) for broadcast queuing. The NCTAMS MTA also returns a modified acknowledgment of receipt to the originator. The modified acknowledgment should, at the minimum, state that the message has been received by the NCTAMS for GBS queuing and indicate receipt date and time. This informs the message originator not to expect immediate receipt or read acknowledgments from the intended recipient, as DMS standards mandate. The NCTAMS' messaging system can also relay acknowledgment of GBS message transmission (or when it will be transmitted) back to the originator. In essence, the NCTAMS acts as the connectivity point for broadcast messages addressed to all underway tactical units within its area of responsibility.³ Figure 8 is a simple overview of the proposed routing scheme and how it incorporates the anycast and mobile IP concepts.

For the proposed scenario, the "com-shift" message initiated by GETTYSBURG prior to getting underway informs NAVCOMSTA Mayport (home agent) to route all traffic to NCTAMS LANT (foreign agent). NCTAMS LANT, also informed of GETTYSBURG's underway status, accepts responsibility as

³ This could occur in much the same manner that it does now. It is expected that extension of duplex DMS connectivity to tactical units will also occur via the current NCTAMS sites.

GETTYSBURG's foreign agent, returns DMS message acknowledgments and reroutes message datastreams to the GBS subsystem for transmission. DMS traffic sent to GETTYSBURG's IP address (now shared amongst itself, NAVCOMSTA Mayport and NCTAMS LANT as an anycast address) will either be routed to NAVCOMSTA Mayport, who then tunnels them to NCTAMS LANT, or directly to NCTAMS LANT for broadcast.

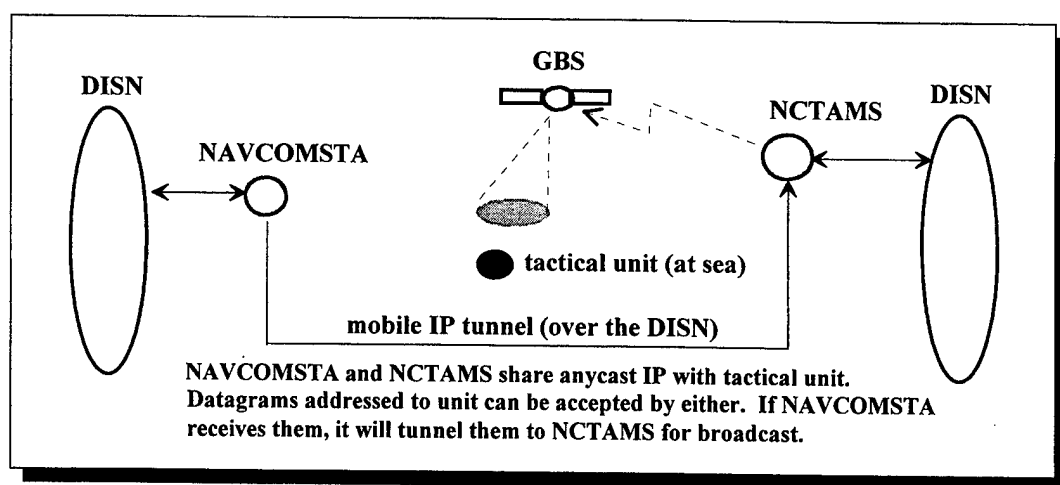


Figure 8. Proposed Mobile IP/Anycast Routing Scheme.

The use of anycast addresses ensures that all DMS traffic is received either at the NAVCOMSTA or the NCTAMS, depending on which is the nearest interface. Remember that the current IPv4 ties a node to the network from which it received its IP address. This means that the tactical unit (while in homeport) is seen as a node of the NAVCOMSTA's DISN subnet, and that subnet will be advertised as the physical location of the unit, even when it is not there. While underway, the anycast address scheme insures that mobile tactical users can maintain at least one network interface at all times, therefore maintaining

network connectivity. It also overcomes the need to update and/or change a unit's IP address just because it changed its network interface (e.g., moves from one NCTAMS to another). While inport, and directly connected to the DISN, the sharing of anycast addresses is discontinued (by a com-shift message) and the tactical unit regains sole ownership of its unique IP address.

A simple routing scheme for mobile units can be developed using just the mobile IP construct previously outlined. However, this would force all message datagrams to be initially routed to the unit's home agent (homeport NAVCOMSTA). The home agent would then retransmit these datagrams to wherever the mobile unit was physically located at the time (foreign agent). The anycast address scheme minimizes this network routing overhead by allowing several interfaces to advertise the IP address of a mobile unit. For instance, message datagrams from an originator located in Japan wishing to send a message to HOUSTON should not (normally) have to travel all the way to the HOUSTON's homeport NAVCOMSTA (in San Diego, CA), to then be rerouted to NCTAMS WESTPAC for broadcast. Ideally in this case, the nearest interface will be NCTAMS WESTPAC, who maintains direct GBS connectivity with HOUSTON.

In another example, SPRUANCE enters the Mediterranean and shifts communication guard from NCTAMS LANT to NCTAMS MED. A com-shift message informs NCTAMS LANT to drop SPRUANCE's IP address from their routers, and NCTAMS MED to add it to theirs. Now all DMS datagrams intended

for SPRUANCE are routed via the DISN to either NAVCOMSTA Mayport (who then tunnels them to NCTAMS MED) or directly to NCTAMS MED for GBS broadcast. Anycast addressing allows NAVCOMSTA Mayport to maintain a continuous network interface for SPRUANCE messages, even during NCTAMS transitioning periods.

3. DMS Broadcast to an Embarked Unit

Message traffic addressed to an embarked unit (e.g., COMDESRON 2) is routed in a similar manner. The embarked unit is responsible for initializing an anycast address in conjunction with their host unit. There are two methods by which this can be accomplished:

- The embarked unit notifies its homeport NAVCOMSTA of which host unit it will be underway in. The embarked unit then shares the anycast address of its host unit, and does not have to add its own IP to the NCTAMS routers. This helps in the reduction of routing table size and update frequency. However, the IP address of the embarked unit must be integrated into the routing tables of the host platform, who segregates and internally routes messages to the embarked unit. Embarked units assigned to ships with a single MTA ships would benefit from this method.
- The embarked unit acts like a stand alone entity and sends messages to update both their NAVCOMSTA and NCTAMS routers. A key advantage is the ability to individually receive traffic if the host unit can support multiple MTAs, each linked to a GBS receiver. This configuration is most appropriate for larger platforms such as command ships, aircraft carriers and amphibious vessels.

In either case, all subsequent message routing instructions are delineated by com-shift messages. A com-shift message from a tactical unit to a NCTAMS can include the IP addresses (and email addresses) of all embarked units (e.g., helicopter squadrons, meteorological detachments, embarked staffs and marine

detachments). This concept allows embarked units to maintain the same IP address regardless of whether they're in port or at sea.

In the scenario, DMS messages addressed to COMDESRON 2 are routed to either NAVCOMSTA Norfolk (who then tunnels them to NCTAMS MED) or directly to NCTAMS MED, who accepts receipt and queues the messages for GBS broadcast to SPRUANCE. SPRUANCE's MTA then sorts and routes the messages to COMDESRON 2's UA.

4. Shipboard Message Flow

The GBS broadcast, transmitted at 1.544 Mbps or 23 Mbps depending on CINC requirements and the tactical unit's geographic position, is captured by one or more small shipboard receive antennas⁴. The ATM datastream, specifically the channel carrying DMS traffic, is demultiplexed and decrypted. The GBS terminal accepts only those data cells addressed to the unit, discarding the rest. In the case of DMS, the error-corrected and in-sequence message datastream is routed to the ship's MTA (most likely the current NAVMACS II) for X.400 address profiling, and routing within the ship's network to the intended recipient's UA. The first datagrams received by the MTA initiate a CMTP-based message transfer session. Use of the CMTP protocol allows the recipient (shipboard) MTA to accept the datagrams without a P1 level connection between itself and the originating (NCTAMS') MTA. The NAVMACS II can also be configured to

⁴ Most certainly, more than one antenna, linked by a shipboard LAN, is necessary to improve signal reception, system survivability, reduce topside placement constraints and allow for multiple MTA configurations.

transmit message receipt/read confirmations over a duplex link, if required. The ability of NAVMACS II to act as a DMS MTA was proven during tests aboard USS KITTY HAWK (CV 63) in conjunction with the Joint Warrior Interoperability Demonstration 1995 (JWID 95) [Ref. 19]. Figure 9 depicts the proposed shipboard data and DMS message flow.

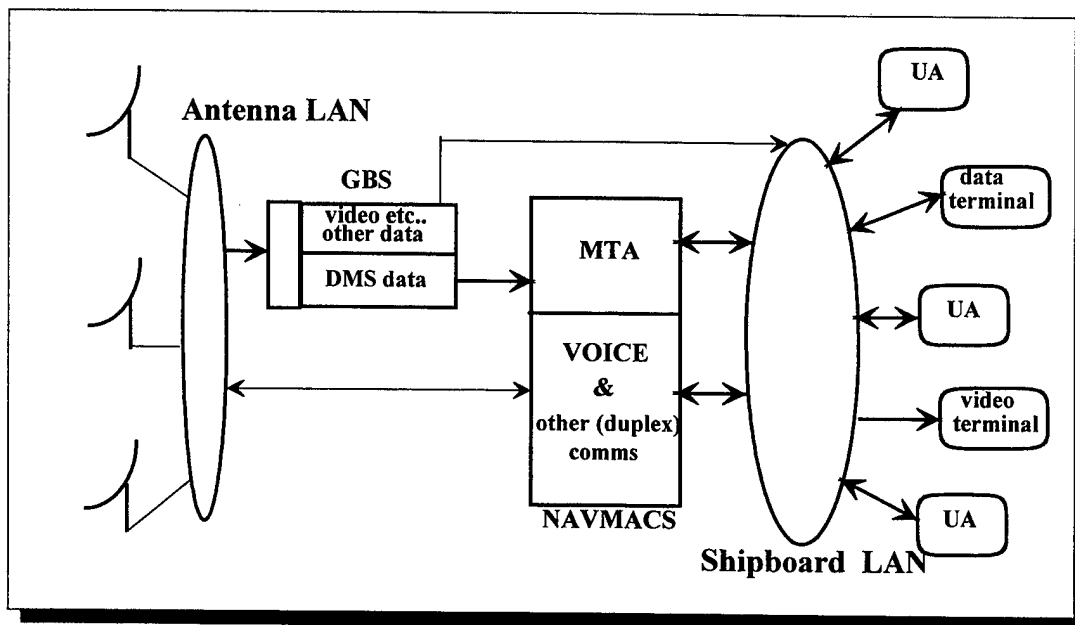


Figure 9. Shipboard Data/Message Flow.

D. DOCTRINAL ASPECTS: SMART PUSH, USER PULL

The proposed system allows for a more robust management of tactical broadcast messaging. For instance, along with the shift in communication guard and DMS message acknowledgment, the NAVCOMSTAs and NCTAMS are tasked by each unit of any special priorities, long-term storage needs and GBS broadcast requirements. These instructions act as the "smart warrior pull" aspect

of this tactical DMS concept.⁵ Proper application of broadcast, computer, email and network technologies can greatly enhance the tactical user's ability to specifically tailor their data communications service needs, regardless of how they connect to the network. Some examples of this concept are outlined below. References to the given operational scenario are delineated in *italics*.

1. Specific Times to Transmit Messages

DMS guidelines call for at least ten days of message storage capacity. This needs to be higher, especially for those units with irregular communications needs.

HOUSTON, due to operational necessity, has irregular communication black-outs. She has instructed NCTAMS WESTPAC to hold all IMMEDIATE and below DMS traffic for bulk GBS transmission at preset times or after she has contacted them. Notifications of FLASH traffic (and higher) are made using current systems (e.g., HF, VLF). The high priority messages are transmitted continuously over GBS until acknowledgment of receipt (verbal or message or both) is received at the NCTAMS.

ALTAIR, whose operational message traffic requirements are much lower than most other units, has all DMS traffic broadcast to her four times daily.

GETTYSBURG, SPRUANCE and COMDESRON 2 have all their DMS traffic

⁵ User-defined messaging parameters are not a new concept. However, continued application of Internet-based technologies, such as WWW and email in the tactical environment, offers several new possibilities on how those parameters are defined, exchanged and updated [Ref. 8].

queued and transmitted over GBS upon receipt at NCTAMS LANT and NCTAMS MED.

2. Receipt Confirmations

Tactical users will dictate how receipt of messages will be accomplished (e.g., in bulk). This can be done over duplex links, with the tactical unit transmitting a database of received message date-time groups twice daily. Messages not confirmed as received can be automatically retransmitted by the GBS system. Confirmation of message receipt and read by the tactical recipient is transmitted over duplex DMS links back to the originator, if required.

COMDESRON 2, expecting a heavy DMS traffic load during operations in the Adriatic Sea, instructs NCTAMS MED that only IMMEDIATE and above precedence messages will be confirmed as received. Receipts will be accomplished in bulk format, three times daily. Originators of all other DMS traffic will receive a preformatted message stating that "your message addressed to COMDESRON 2 has been transmitted over GBS. Due to operational constraints no direct acknowledgment of receipt by COMDESRON 2 is expected".

3. Routing Instructions for High Priority Messages

This concept allows the tactical user to tailor the transmission of high-priority messages. For example, all FLASH traffic can be sent over GBS and/or duplex systems continuously until receipt is acknowledged.

GETTYSBURG, expecting notification of possible surge-deployment to the Caribbean, has instructed NCTAMS LANT to route all FLASH traffic over both GBS and duplex systems to improve probability and speed of reception.

4. Storage of Messages With Certain Header Data

NAVCOMSTA and NCTAMS local message stores can hold specified message types/addresses until the tactical unit can "log in" to the DISN and download them. This concept closely follows the Navy's current "gateguard" communication architecture.

GETTYSBURG instructs NCTAMS LANT to hold all ROUTINE DMS traffic during their 2 day transit from Mayport, FL to Norfolk, VA.

E. ADVANTAGES

The proposed DMS broadcast over GBS (DMS/GBS) concept offers several advantages, each presented below.

1. Simplicity

This concept outlines a simple yet scaleable broadcast capability which can be integrated into other tactical DMS implementation efforts. It resolves the problem of TCP connectivity over a connectionless link, overcomes the mobile-user restrictions of the current IP protocol, while also addressing the connection needs of the X.400 application protocols. The only new development required is a completion of the CMTF to replace the current P1 protocol.

Moreover, it outlines a new, compatible method of TCP/IP-based messaging

over the existing DISN infrastructure that accommodates the unique limitations and needs of the mobile user.

2. Performance

DMS/GBS offers an order of magnitude jump in broadcast technology over the existing Fleet Broadcast system, one that also integrates mandated DMS interoperability. Whether the data is transmitted at 1.544Mbps or 23Mbps, the jump in throughput performance makes GBS a logical choice for large scale, tactical, data dissemination. Appendix C depicts a comparison of data throughput performance using various military communications system, highlighting the gain in message delivery speed offered by GBS.

3. Security

There is no reduction of MISSI security standards. Datagrams (DMS messages) are not decrypted by the intermediate interfaces, only repackaged and rerouted. Transmission over the GBS, with bulk encryption of the datastream, adds another layer of security to DMS message dissemination.

4. Relief of MILSATCOM Burdens

DMS/GBS implementation offers a reduction of message traffic congestion over the current duplex MILSATCOM systems. With the vast majority of operational traffic to tactical units handled by the DMS/GBS system, duplex systems can better accommodate high-priority messaging, GBS user service requests and shore-bound DMS traffic from the tactical units.

5. Near and Long-Term Utility

The proposed system offers a near-term tactical DMS utility while more robust duplex links are developed. It also identifies the frame-work for a long-term DMS broadcast link. Furthermore, the routing and transport concepts applied in this system (mobile IP, anycast, IPv6) can be adapted to any IP routed data network in order to achieve a mobile user connectivity.

F. LIMITATIONS

There are two primary limitations imposed by this concept. However, the limitations apply to all other current tactical DMS proposals as well. Neither limitation affects the scalability, connectivity or capability of service, only the elements of service available to the tactical DMS user.

1. Receipt Acknowledgments

Under the DMS/GBS concept, immediate acknowledgment of message receipt or read by the intended recipient is not available. Only receipt/queuing acknowledgments by the responsible NCTAMS are immediately returned to the originator. However, delayed acknowledgments can be initiated by the tactical unit via a duplex DMS link.

2. X.500

The ability to immediately search the distributed X.500 directory of X.400 addresses and user data cannot be accomplished over the proposed system.

However, tactical units can download the current X.500 database (or subsets of it) prior to getting underway. Once at sea, updates to the database can be requested via duplex links and transmitted to the tactical unit via the GBS broadcast.

G. CONCEPT SUMMARY

In summary, the challenge of broadcast DMS extension to the mobile tactical unit is resolved using new routing techniques and high throughput broadcast links. When underway, units maintain anycast addresses with their homeport NAVCOMSTAs and with the individual NCTAMS accepting traffic for them. DMS messages addressed to a tactical unit are sent to the nearest interface holding that unit's anycast address. If the nearest interface is the ship's homeport NAVCOMSTA, and the ship is out of homeport, then the message datagrams are encapsulated and rerouted by the NAVCOMSTA to the NCTAMS. If the nearest interface is the NCTAMS itself, then no further routing is required; receipt of the message is acknowledged and it is queued for GBS transmission. The transport and application layer protocol problems, outlined in Chapter I and in the introduction of this Chapter, are resolved by having the NCTAMS' routers conduct all error checking, retransmit requests and datagram sequencing prior to queuing message datagrams for ATM broadcast over GBS. The application of CMTP protocols at the NCTAMS and shipboard MTAs allow DMS datagrams to be successfully transmitted over a simplex link. The result is an in-sequence and

error-free DMS datastream transmitted over a high-speed simplex link to the tactical user.⁶

The proposed system relies on the integration of IPv6, CMTP and the use of mobile IP constructs within the DISN environment. There are also some hardware, infrastructure and management issues which must be concluded before this system can be implemented. These issues, and proposals for their resolution, are the focus of the following chapter.

⁶ The concept of using an intermediary router which maintains a duplex link with one node and a simplex link with another was originally developed for use in network security. This concept allows unclassified nodes to pass traffic to classified nodes, but stops any transfer of data from a secure node to a unclassified node. The intermediary router receives datagrams from a unclassified node via a duplex link, generates acknowledgments to the sender, repackages the datagrams with error correction and sends them out a separate simplex link to the classified recipient. In this manner the unclassified node has no direct access to the classified network but can still pass data to it; while the classified nodes cannot transmit to the unclassified network.

V. RECOMMENDATIONS AND CONCLUSIONS

The previous chapter outlines a concept of operations for a high data-rate, DMS-capable broadcast service. The actual implementation of this concept relies heavily on the application of recent technologies and the resolution of specific issues within the developing DISN framework. An information distribution system, such as the proposed DMS/GBS system, is only as robust and effective as the underlying network which supports it (DISN). Improvements, therefore, in the effectiveness of the common network benefit all subsystems which rely on it. The proper design of a supporting network should be the first priority in the restructuring of the military's information distribution system. Furthermore, this design must include data distribution standards to which all network clients must conform. It is no longer fiscally or technologically effective or efficient to design and implement independent information subsystems only to later force their interoperability over a network. This "network-centric" approach to information distribution systems provides the greatest freedom for subsystem design while simplifying any future network and subsystem expansion [Ref. 8].

A. NEAR-TERM RECOMMENDATIONS

The following recommendations should be viewed as a list of technologies which can be applied to expand the usability, scaleability and performance of the overall DISN. These specific recommendations can be implemented in the near-term to improve the DISN without significant DoD development or network

restructuring. The generation of a comprehensive set of requirements for implementation of the proposed DMS/GBS system is left for a follow-on effort.

1. Infrastructure: World-Wide GBS Coverage

There is currently no better alternative for expanding the information broadcast capabilities of military communications than with the GBS. The military's requirement to project a presence anywhere in the world mandates that its supporting information infrastructure be based on global connectivity. The modification and launch of all three GBS-capable UFO satellites (#8, #9, #10) should be considered a minimum first step in establishing a very critical aspect of this capability. A initial assessment of GBS as a dissemination system for DMS can be made using the current testbed GBS (CONUS-based) system operated by the NRO.

2. Accelerated Development / Fielding of CMTP

The Connectionless Message Transfer Protocol promises to alleviate X.400 of its restriction to duplex-only links. Until this protocol is fully developed, the US Navy Fleet Broadcast subsystem (albeit, all broadcast systems) will remain unable to transmit X.400 messages without extensive format conversion and a severe reduction of the tactical user's DMS elements of service. Delays in the development and application of CMTP translate to a continued degradation in DMS connectivity to the tactical environment.

3. Application of IPv6 on the DISN

The proposed DMS/GBS system relies heavily on IPv6's anycast address scheme. However, IPv6 should be applied to the DISN architecture not because it is required by any one system or proposed concept, but because it supplies a vastly improved routing and addressing structure to a network. IPv6 therefore allows for extended network growth and the application of more robust information management schemes. If for no other reason IPv6 should be implemented on the DISN for its expanded address space and multicast capabilities.

4. Application of the Mobile IP Concept

In much the same manner as IPv6, Mobile IP constitutes a commercially developed, backward-compatible concept which expands network capability without affecting the overall network structure. As military data communications move toward the DISN vision, Mobile IP offers a near-term, relatively simple, yet effective method of integrating the highly mobile subscriber without development of proprietary protocols or subnets. Implementation and testing of this concept on the Navy's NCP II can be made with little or no disruption to operational message traffic.

5. NCTAMS as DMS and GBS Theater Management Centers

As theater-wide routing and switching centers, NCTAMS already provide a key link between the Navy's information networks and the warfighter. If DMS and GBS are extended as planned to the warfighter arena, they should be

placed under the operational control of the theater CINCs. Uniting these subsystems and their theater-level management operations under one NCTAMS roof means not having to add new networking layers to a CINC's communication infrastructure.

B. LONG-TERM RECOMMENDATIONS

It can be effectively argued that the most important aspects in the development and implementation of any information system are a clear strategic vision of that system's intended application and the realization that continual improvement as a function of the architecture must be incorporated into the initial design. However, these design issues are probably the most difficult to detail as well. This is especially true in the case of the DISN, GBS and DMS, where the system has already been designed and implementation has begun. Therefore the following long-term recommendations are of a more technological rather than design nature. While these recommendations are founded in the improvement of the current DMS and GBS, they are not entirely based on what is required to implement the proposed DMS/GBS system. They should be seen as general comments and opinions on what may assist in providing a robust, long-term military data communication infrastructure.

- **Continued expansion of the GBS earth coverage.** The current three satellite constellation constitutes the minimum required; it does not provide for system redundancy or polar coverage.
- **Integration of the (still under development) Low Earth Orbit Satellites (LEOS).** This commercially developed satellite-based system is aimed at world-wide voice and data connectivity. These systems represent a (promised) large-scale upgrade in world-wide networking and

information distribution. DoD should prepare integration plans and system implementation analysis before, not after, these systems are placed in service. Anticipation of this capability may reduce the initial lag in effective information management integration which has challenged the GBS.

- **Maintain the VLF, HF and UHF systems as back-ups.** They are paid for, in-place and operational. Why limit the channels of dissemination? HF systems remain the only non-satellite, long-haul communication link, and VLF stands as the only means to communicate with submerged submarines. As such, the VLF and HF media act as needed complements, not competition, to satellite-based systems and should be integrated into the DISN infrastructure [Ref. 8].

- **Maintain (expand on) an X.400 to SMTP connectivity.** Simple Mail Transfer Protocol (SMTP) is the standard for email communications within the commercial Internet. DMS users will require connectivity to email systems outside the DoD, and it appears that there will be very little X.400 market penetration into the commercial world. Furthermore, as development of SMTP and associated email protocols continues in the commercial arena, DoD may well have to reconsider its adoption of X.400.

C. AREAS REQUIRING FURTHER STUDY

This thesis presented a general concept of operations for a DMS/GBS broadcast system. The next logical step in the development of this concept is the accurate modeling and simulation and prototyping of the proposed system. Several individual technologies (e.g., IPv6, Mobile IP, GBS, CMTP) were incorporated in order to arrive at the final system concept. Obviously, continued analysis of each individual technology and its application to the military communications environment is required. In the case of the proposed DMS/GBS concept, the simulation and integration of the several individual parts should be the modeler's first priority. Accurate system simulation, if even possible, may well prove a secondary fallout of what is learned by the efforts undertaken to

integrate these individual technologies. Specifically, any modeling/simulation efforts based on the proposed concept should:

- **Test the NCP's ability to act as "intermediary" TCP/IP relay system which ties together duplex and simplex links.** What hardware, software and management are required to enact this integration? What time delay and data overhead is added?
- **Test the general scalability of the proposed anycast IP concept, specifically at the NCTAMS router.** How many users can effectively be supported by one NCTAMS router? Based on delivery times, scalability and ease of use, is the concept better than re-assignment of IP addresses to mobile units?
- **Evaluate the usability of Mobile IP in a dynamic tactical environment.** What constraints or limitations are there in the scalability of this concept to an entire fleet or Navy? What data delivery delays are introduced? What hardware/software modifications are required by the home and foreign agents? What are the security considerations?
- **Test the capabilities and limitations of CMTP (when available).** Does it really allow a simplex MTA connectivity? Can it coexist with the standard P1 protocol? What quality of service limitations are imposed? How can the capability be best implemented and managed?
- **Examine what hardware/software modifications are required to integrate the GBS datastream and the shipboard MTA (NAVMACS?).** Are (low data-rate) back channels required to effect a reliable link? What are the effects and consequences of unexpected link disruption caused by atmospheric disturbances on message delivery?
- **Examine addressing issues.** Operational messages are traditionally sent to a unit, not an individual. What doctrinal changes are required (if any) to support, manage and exploit (limit?) the addressing capabilities of DMS?
- **Outline network management.** Develop a comprehensive (end-to-end) plan for automated network management, to include fault location, maintenance and restoration. Model system performance under stress (jamming, node destruction, peak traffic loading, and environmental factors).

While not the focus of this thesis, it should be noted that there remain several alternatives and unanswered issues in the seamless extension of *duplex tactical DMS*. These varied alternatives, which encompass both technological and information management aspects, require further exploration, analysis and testing. The issues include such topics as:

- **Modeling and testing of the proposed MFI (Multi-Function Interpreter) concept.** What overhead, errors and time delays are added to the system by its use? How does the reduction in DMS elements of service caused by the MFI effect the tactical user and/or the message originator?
- **Alternatives to the continued use of low-rate MILSATCOM systems for DMS tactical connectivity.** What military or commercial communications systems are in development which can increase DMS connectivity and system availability at the tactical level?
- **DMS personal messaging.** DMS extends messaging capabilities down to a personal, vice the traditional, unit level. How will this affect the overall operational DMS? What doctrinal and operational (security?) implications are involved?

D. CONCLUSIONS

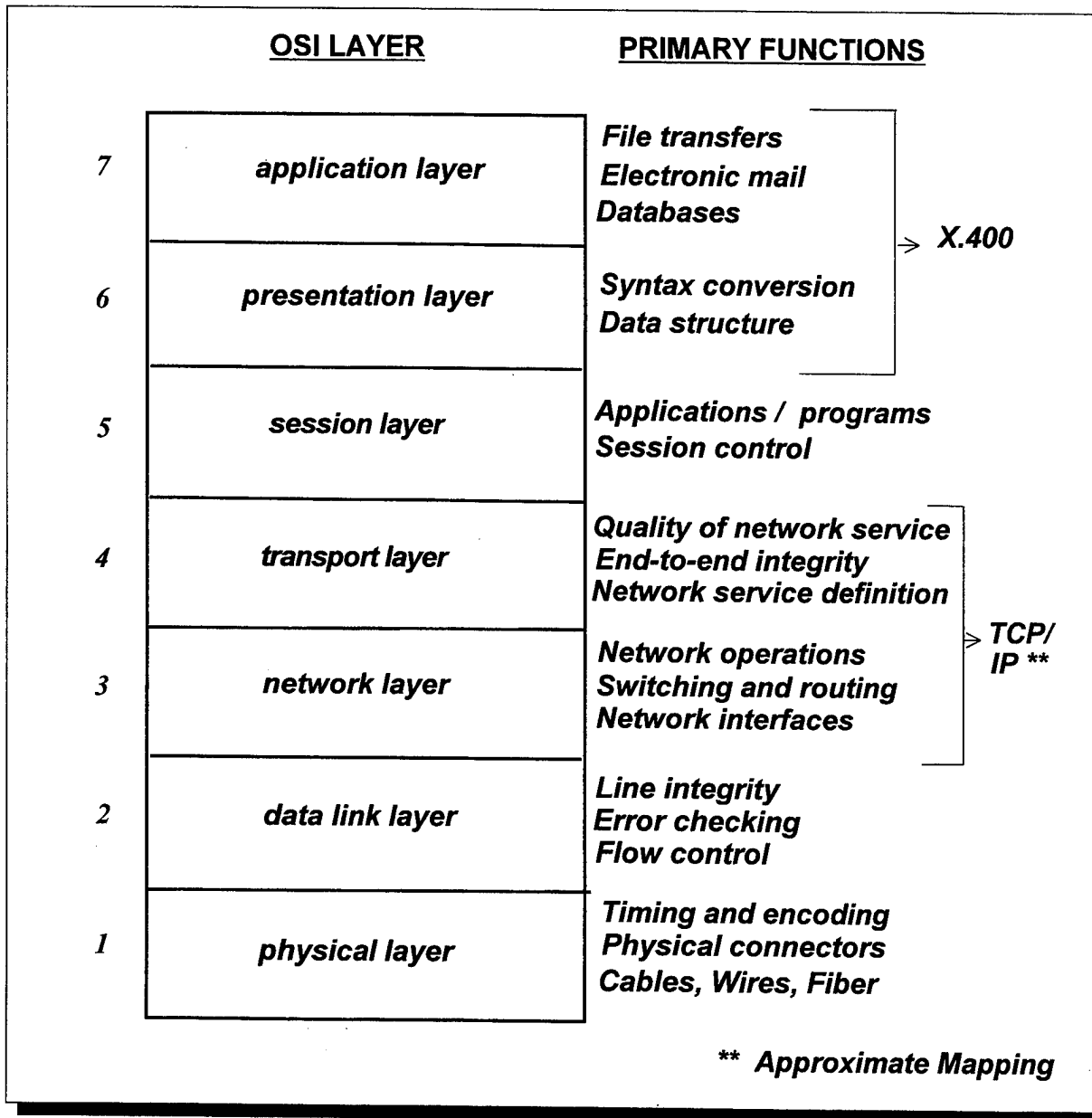
DoD messaging is moving to the Defense Message System. Ultimately, DMS will be implemented in all DoD environments: tactical, strategic, fixed and mobile. However, while DMS efforts are aimed at providing multimedia messaging capabilities, the networks used to pass these messages are not being expanded to meet the new requirements. The Navy's Fleet Broadcast subsystem is particularly ill-equipped to handle DMS traffic. Broadcast systems are, however, an integral and, with GBS, a growing part of modern military communications, especially during covert or emission controlled (EMCON)

operations. The Navy's Fleet broadcast must be modernized if it is to become a seamless extension of the DMS infrastructure into the tactical environment.

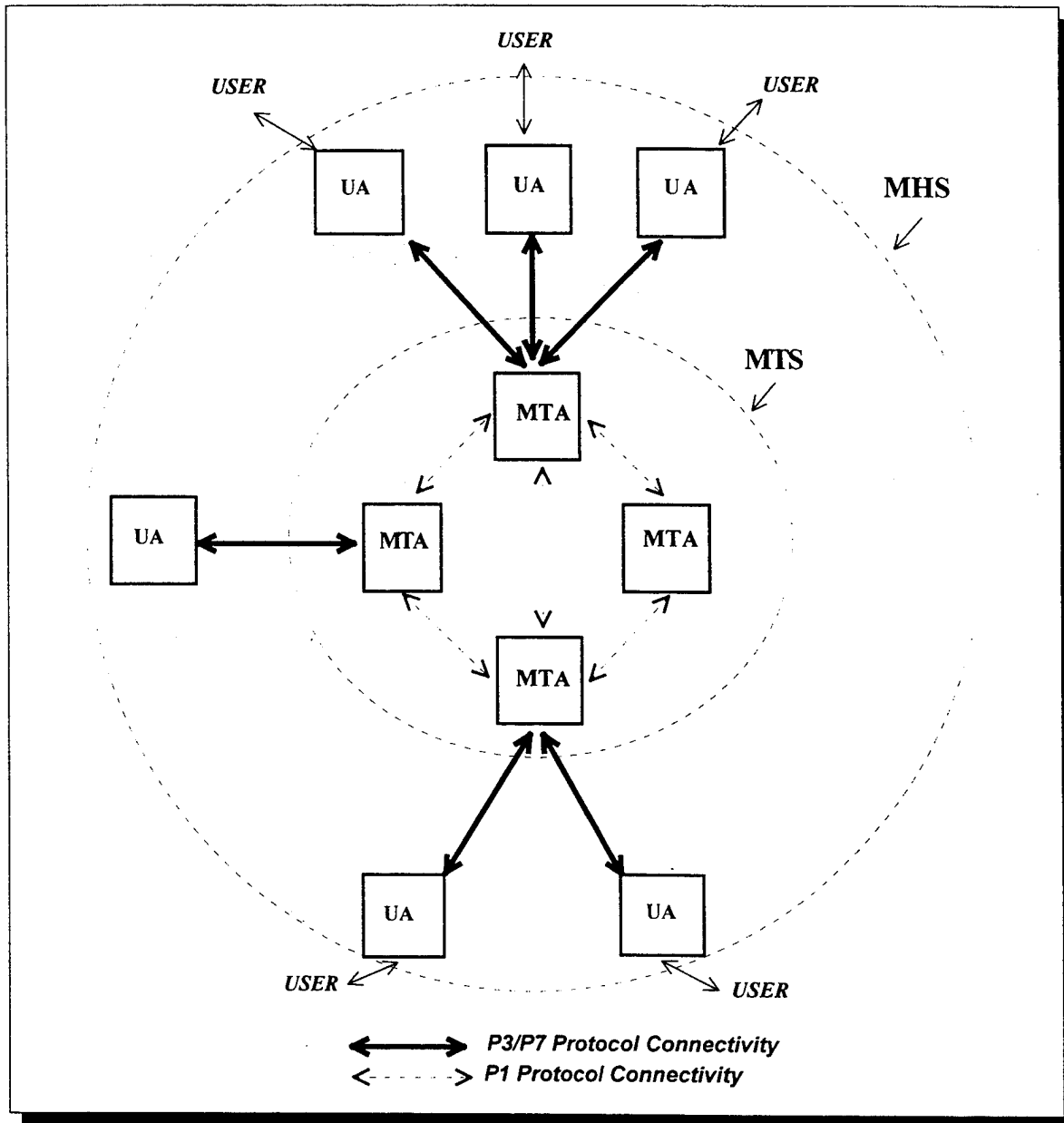
At the same time the US military is developing a new satellite-based data dissemination system known as GBS. Early applications of GBS are aimed at theater-wide database updates and video broadcast. However, this system can also be used as a new high-throughput message dissemination service. The GBS in effect becomes a new Fleet Broadcast subsystem. In this manner, not only is the broadcast capability of DMS expanded, but the overall load on duplex MILSATCOM systems is reduced.

This thesis attempted to present one possible method of integrating the DMS and GBS systems. This effort was undertaken in order to explore how the DMS messaging capability could be extended to the mobile, tactical user via a new, more robust broadcast subsystem.

**APPENDIX A. OPEN SYSTEMS INTERCONNECTION (OSI)
REFERENCE MODEL. AFTER REF [21].**



APPENDIX B. X.400 ENVIRONMENTS, COMPONENTS AND INTERFACE PROTOCOLS



LEGEND

MTA: Message Transfer Agent
 UA: User Agent
 MHS: Message Handling System
 MTS: Message Transfer System

**APPENDIX C. DATA THROUGHPUT COMPARISONS OF
VARIOUS SYSTEMS. AFTER REF [20].**

Representative System And Throughput

	75 bps	2.4 Kbps	512 Kbps	1.54 Mbps	23 Mbps
	Current FLTBCST	MILSTAR & UFO (duplex)	NIPRNET SIPRNET	GBS@ 2000nm	GBS @ 500nm
ATO @ 1.1 Mbytes	32.6 hours	1.02 hours	17.2 sec	5.71 sec	.38 sec
T-Hawk MDU @ 30kbytes	53 min	100 sec	.46 sec	.17 sec	.01 sec
Text Only * DMS msg 7.5 Kbytes	13.33 min	25 sec	.117 sec	.038 sec	.002 sec

-All transmission times calculated using:

[8 data bits per byte * msg size] / system throughput

-Message sizes are strictly information content and do not account for encryption, error correction, enveloping or transmission protocol overhead bits, which can vary depending on transmission system used.

* Based on three times the current AUTODIN average message size (see Chapter I), no multimedia attachments.

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